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The lake whitefish Coregonus clupeaformis (Mitchill) in Flathead Lake Montana

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THE LAKE WHITEFISH, *COREGONUS CLUPEAFORMIS* (MITCHILL), IN FLATHEAD LAKE, MONTANA

by

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Dr. George Marsaglia and the staff of the Statistics Laboratory, Montana State University, prepared the length-weight regression lines.

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INTRODUCTION

Although a great deal has been written about the lake whitefish, Coregonus clupeaformis (Mitchill), in Canada and the Great Lakes region of the United States, where it is one of the commercially important species of fish, little is known of this species as it exists in the lakes of northwestern United States. It is the objective of this investigation to study the natural history of the whitefish in Flathead Lake, Montana, with emphasis on age, condition, food-taking and depth distribution in Yellow and Polson Bays. Special subjects - such as movements, the effects of temperature cycles, sex ratios and sexual maturity - also will be treated in so far as the data permit or suggest. If, in the future, it is desired to bring this valuable food species under management in Flathead Lake, at least a partial life history will have been made available to the manager. Furthermore, additional knowledge to the general productivity of, and related problems in, Flathead Lake, one of the major inland waters of the United States, will have been gained.

The lake whitefish is presumed not to be indigenous to western Montana. Its history in Flathead Lake apparently has been relatively brief, according to Elrod (1929).

In his review, Elrod states that, "A planting of some three million fish, secured from the United States Fish Commission, taken from the Great Lakes, placed in the lake prior to 1916, seemed to have disappeared. Repeated search failed to produce a single specimen. In 1916, during the months of July and August, 1,250 feet of gill net were placed at various places in the lake, from shallow water to 200 feet in depth. No 'Lake Superior' whitefish were taken. As they do not take the hook they had to be sought with nets.

"A few years later eggs were secured from fish taken at St. Mary Lake in Glacier National Park. Presumably from these eggs but possibly from the first planting, the fish now taken from the lake have developed, but they are not abundant." It is probable that the 1916 gill nettings were made by Dr. Elrod while he was Director of the Montana State University Biological Station at Yellow Bay.

Recently Brunson and Newman (1951) reported on the summer food of the lake whitefish in Yellow Bay. No other references to past investigations of whitefish in Flathead Lake were found.

From the meager information available, the writer has attempted to determine the possible disturbance (see note at bottom of page 19) of the population prior to this investigation by estimating the extent of exploitation in the past.

Flathead Lake, is approximately 30 miles long and averages about 7 miles wide. Its southern half lies within the Flathead Indian reservation. Concerning hunting and fishing rights of Indians and whites, section 26-131 of the *Revised Codes of Montana* (1947) states, "In the Indian treaty of 1855 between the United States represented by Isaac I. Stephans [sic. - correctly spelled Stevens] governor and superintendent of Indian Affairs for the Territory of Washington and the Chiefs, headmen, and delegates of the confederated tribes of the Flathead, Kootenai and Upper Pend d'Oreille Indians, the said Indians were given the exclusive right to hunt and fish on the Flathead Indian reservation, and the privilege of hunting in their usual hunting grounds on large areas of Montana. Non members of these tribes hunt and fish on Indian lands by sufferance of such tribes only."

However, the *Revised Codes of Montana* (1947) also grants, section 26-132, the Montana State Fish and Game Commission the "power to negotiate and conclude agreement with the council of Confederate Salish and Kootenai tribes of the Flathead Indian reservation establishing for citizens of Montana, regularly licensed to hunt and fish in the state, the privileges of hunting and fishing on the Flathead Indian reservation." The agreements which followed these laws have, in effect, allowed hunting and fishing by whites on Indian lands, common open and closed seasons for whites and Indians alike, State permits to Tribal Indians to hunt and fish without charge, and stocking and policing of hunting and fishing areas within the reservation. Another result of the agreements is that gill netting by either the Indians or whites in any part of the lake is not legal. The few fish taken by that means prior to the agreements probably have had little effect on the present population.

Present exploitation is by hook and line method. It is common knowledge that some fish are taken by this method by the Indians in the Finley Point region. In addition, ice fishing in the bays in January and February yields a few whitefish; and in early summer a few whitefish are taken from the Polson city docks. It is apparent that the whitefish population of Flathead Lake is, for all practical purposes, unexploited.

A REVIEW OF THE PERTINENT LITERATURE CONCERNING *COREGONUS*

Taxonomy and Distribution.

An intensive discussion of the taxonomic work concerning *Coregonus* is not intended in this review. However, in passing, mention is made of recognized systematic work which might be of importance to population studies.

Koelz (1929) indicates that the known distribution of the coregonids is circumpolar and is confined to the temperate and arctic regions of the northern hemisphere. Hart (1930) states that *Coregonus clupeaformis* is distributed from the Arctic to the northern United States and from the Rocky Mountains to the Maritime Provinces. Obviously plantings have somewhat extended its natural range.

Most present day taxonomists accept the Coregonidae as being of family rank in the order Clupeiformes. The systematic position of the species has been ably summarized by Hart, (1930) and reflects the attitude of the majority of contemporary taxonomists. Hart writes, "Jordan and Evermann (1896) recognized two species of whitefish in central and eastern North America, *Coregonus clupeaformis* (Mitchill) and *Coregonus labradoricus* (Richardson), both species occurring in the Great Lakes. In Jordan and Evermann (1911), however, *Coregonus albus* (Le Sueur) is assigned to the lake Erie whitefish and the whitefish of the other Great Lakes considered as being *Coregonus clupeaformis*

(Mitchill) and this statement occurs: 'Possibly *Coregonus albus* is merely an ontogenetic species, its peculiarities being due to the condition of food and water in Lake Erie.' Koelz (1929) considers this last suggestion as being the true interpretation, for he places in the one species, *Coregonus clupeaformis* (Mitchill), all the whitefishes of the Great Lakes.

"In view of the known variability of the genus, the certain knowledge that body form is modified by captivity (Koelz, 1929), and the evidence cited by Dymond and Hart (1927) for Coregonidae, and Hubbs and Whitlock (1929) for *Poecilona caeiliorum*, that body proportions may be altered in definite directions by different conditions, it appears advisable until specific differences have been established by biological studies, to consider as one species all the forms and races of *Coregonus* found in Eastern Canada."

Monti (1933) studying an European species of *Coregonus*, found that the whitefish which were introduced into Italy fifty years previously had features so modified as to defy identity with their ancestral stock once development had progressed beyond the larval stage. Morphological characteristics were found to vary from lake to lake according to physical and biological conditions. This has also been found true for the North American species. Monti concludes, "The Italian whitefish belong to a single natural species, Coregonus lavaretus, which retaining its mainly steno-thermic character, is remarkably plastic and capable of modifying its external form according to the life conditions encountered in various surroundings; thus in time a local 'nacio' is developed."

Dymond (1943) reduced to synonymy the many previously described species of Coregonus from northwestern Canada. He believed that most of the morphological variations which were found in the populations of the different waters of that region showed ecological rather than geographic variation. It is apparent, then, that Coregonus clupeaformis has considerable capacity for morphological variation, but that all North American forms are probably of one species. Most modern taxonomists apparently are unwilling to make subspecific designations. As a result, whitefish work in the various lakes is on a population level.

The lake whitefish of Flathead Lake, regardless of its parental stock, is therefore referred to the species Coregonus clupeaformis (Mitchill). The possibility is recognized, however, that some morphological changes may have occurred since its introduction.

Spawning, Segregation and Sexual Maturity.

As evidenced in the literature, segregation and times of spawning in Coregonus vary both in the same and in difent lakes from year to year and even according to season within a year. Age at sexual maturity varies with the lake and possibly also with the degree of exploitation. In Tables I and II are summarized data from a number of North American Lakes. The figures under 'Sexual maturity - Age' indicate the age at which the majority of the fish become mature. Two sex ratio figures for the spawning run in Lake Champlain are the result of two populations described for that lake. A more detailed discussion of the work pertinent to this investigation will be found in the section on 'Age and Condition.'

Embryology and Early Life History.

Hart (1930) has written a good account of the early life history of Coregonus. His paper outlines the gross developmental stages to the time of hatching, but emphasizes the habits and development of the fry. Physical conditions of the spawning grounds and mortality of whitefish eggs by predators is given superficial treatment. Price (1934a, 1934b, and 1935) used hatchery reared material as a basis for his series of papers on lake whitefish embryology.

TABLE I

SUMMARY OF LITERATURE CONCERNING SPAWNING IN *COREGONUS*

Source	Location	Spawning Period	Duration of Spawning	Character of bottom	Depth (feet)
Bajkov (1930)	Lake Winnipegosis	late Oct.-early Nov.	10 days	humus	3-6
Dymond (1933)	Hudson Bay		anadromous form		
Elrod (1929)	Flathead Lake	winter			
Hart (1930)	Bay of Quinte	early Nov.	*7-10 days	rocky	8-15
Koelz (1929)	Lake Michigan	Nov. 15-Dec. 15	two weeks	honey comb rock, gravel	6-60
Koelz (1929)	Lake Huron	late Oct.-Nov.		honey comb rock, gravel	4-45
Koelz (1929)	Lake Superior	Nov.		sand, gravel, stone	6-72
Koelz (1929)	Lake Erie	Nov. 20-Dec.		rock, gravel	30
Koelz (1929)	Lake Ontario	late Nov.-Dec.		hard bottom	to 90
Koelz (1929)	Lake Nipigon	mid-late Nov.		hard bottom	
McHugh (1939)	Okanagan Lake	late Dec.			
Van Oosten (1923)	New York Aquarium	Ripe in Dec.-Jan.	did not spawn		
Van Oosten (1938)	Lake Huron	Nov.-mid Dec.		honey-comb rock, gravel	6-60
Van Oosten and Deason (1938)	Lake Champlain	Nov.			
Van Oosten and Hile (1947)	Lake Erie	Nov.-Dec.	**one month		

*plus stragglers - most of figures under 'duration of spawning' indicate peak of spawning activity.
**indicates extent of season.

TABLE II

LITERATURE SUMMARY- SEXUAL MATURITY AND SEX RATIO OF COREGONUS

Source	Location	Sexual Maturity: Age ♂	Age ♀	Age *	Weight (lbs.) ♂	Weight (lbs.) ♀	Weight (lbs.) *	Sex Ratio: Non Spawning Run ♂	Non Spawning Run ♀	Spawning Run ♂	Spawning Run ♀
Dymond (1933)	Hudson Bay (anadromous)			VI	1 (min)	1½(min)					
Hart (1930)	Bay of Quinte			V-VI				**** 54	46		
Koelz (1929)	Lake Michigan						1¼-1½				
Koelz (1929)	Lake Huron						2-2½				
Koelz (1929)	Lake Superior						1 (min)				
Koelz (1929)	Lake Erie						1¼-1½				
Koelz (1929)	Lake Ontario						1½-2				
Koelz (1929)	Lake Nipigon						1-1¼				
Van Oosten (1923)	New York Aquarium			II-III							
Van Oosten (1933)	Lake Huron	IV	VI		1½-2½	3		49	51	*** 91	9
Van Oosten and Deason (1938)	Lake Champlain	** II-III	IV							50 56	50 44
Van Oosten and Hile (1947)	Lake Erie	III	IV					50	50	79	21

* sex differences not defined.
** majority may be a year older.
*** early spawning run.
**** data from Shakespeare Island Lake.

Age and Growth.

Van Oosten (1923) not only showed the validity of the scale method in age determination of whitefish but also demonstrated that a correlation exists between annual growth and length of body and scales. Since publication of this classic paper, a wealth of information on age and growth of the whitefish has appeared. By employing a relatively simple projection apparatus it was found possible to calculate the length of an individual fish at the end of each successive year of growth by use of the formula:

$$\frac{\text{length of scale at end of year } x}{\text{total length of scale}}$$

$$\frac{\text{length of fish at end of year } x}{\text{length of fish at time of capture}}$$

By determining a large number of individual growth histories from a population it is possible to derive a general growth curve and make a number of predictions as to the status of that population. Van Oosten concluded that temperature and sexual maturity were most likely the primary factors in the formation of annuli (yearly growth marks) on the scales of whitefish, whereas food was implicated as being a primary influence in annulus formation of immature whitefish. Although these contentions, to the knowledge of the writer, never have been disproved, the existence of different causes for annulus formation in young and adults may indicate that the basic mechanism in annulus formation is not entirely understood.

Although the experimental work of Van Oosten has been an important factor in influencing the number and intensity of whitefish studies, the economic value of the species has, more than plain scientific curiosity, been responsible for much of the age-growth work. The discussion which follows summarizes a number of the age-growth studies of whitefish.

The first important age-growth publication concerning whitefish to follow Van Oosten's report of 1923 was that of Hart (1931a). The growth rate of whitefish in Lake Ontario was found to be greater than in the more northerly Lake Nipigon and Shakespeare Island Lake. The major generalization drawn was that growth in the whitefish is at first rapid and then slow. The reverse was found to hold in the case of weight. No change with growth in the proportion of total weight to weight of viscera was found.

In another publication by Hart (1932) it was stated that whitefish growth for the first three years may be plotted as a succession of sigmoid curves with rapid summer growth followed by a longer period of retarded winter growth.

Dymond (1933), who worked in the Hudson Bay region, found that Coregonus does not grow as large in salt water as in fresh water lakes of the same latitude. The rate of growth, however, was found to be greater than that of whitefish in Lake Nipigon and slower than in Lake Ontario.

Hile and Deason (1934) credited the slow growth of whitefish in Trout Lake, Wisconsin, to the great density of the total fish population, particularly of the lake herring, in the hypolimnion of the lake. The crowding was believed to have impeded the growth rate through the operation of a "space-factor." The "space-factor" concept seems to indicate that the real cause or causes of the slow growth rate were unknown.

Some age-growth data from a planted population in Okonagan Lake, British Columbia was presented by McHugh (1939), but the sample was so small as to make the growth curve reliable for only the first three years of life.

Kennedy (1943) found "two groups" of lake whitefish in the little exploited population of Lake Opeongo, Ontario. Size at maturity distinguished the two groups from each other, the size distribution of mature individuals being bimodal. Slight but significant differences in numbers of scales and gill rakers between the two groups were found, but no body measurement differences were found other than those resulting from size differences. Growth histories further distinguished the dwarfed group from the larger size group by revealing the slower growth rate, shorter season of growth, younger age at maturity and shorter life span of the former. The observed differences were not thought to be environmentally caused and the law of compensation of growth was not found to hold as Van

Oosten (1938) found in the Lake Huron whitefish.

Age-growth data for *Coregonus* in the Great Lakes region has been supplied largely through the publications of Dr. John Van Oosten and associates. Van Oosten (1938) based his study of the Lake Huron whitefish on a collection of 982 specimens which were taken in July, 1923, and November 1924, off of Alpena, Michigan. Although collection of the entire sample at one location in a body of water the size of Lake Huron may be considered as a weakness, nevertheless, a number of conclusions were drawn by the author from the study. The summer collection was found to be composed of younger fish than the fall collection which was taken on the spawning grounds. In terms of length the two sexes were found to grow at the same rate, with the females a little heavier than the males at corresponding ages and lengths. Growth was found to be most rapid during the first year and the "law of growth compensation," (i.e., the smallest yearlings of each age group grow more rapidly than the larger yearlings) were found to apply.

Van Oosten and Deason (1938) described the characteristics of the practically unexploited population of Lake Champlain. When analysis of collections which were made during the spawning season from both the north and the south ends of the lake was made a number of differences pointed to a disturbance* of the northern stock. The disturbance to the northern stock was thought to have been caused by licensed commercial seining which began in the northern part of the lake just before the sample was taken. The authors did not feel however, that exploitation alone explained all the observed differences between the two collections. On the basis of the following evidence two whitefish populations were described for Lake Champlain:

"1. Presence of a spawning ground at each end of the lake.

2. Differences in calculated lengths and increments of length (growth rates).

3. Differences in the actual lengths and weights of corresponding age groups at capture.

4. Differences in the coefficient of condition and the length-weight relationship."

Van Oosten and Hile (1947) determined ages and individual growth histories for 3,399 Lake Erie whitefish. Unlike the Lake Huron collection, samples were taken from a number of areas and the data for all samples were combined. Females averaged longer and heavier than males of corresponding age. As in most other studies of the

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*'Disturbance' as employed by Dr. Van Oosten apparently implies some degree of exploitation by man. It is therefore probable that some characteristics of a population may be explained by such a human factor. The word is used in a similar sense in this paper.

whitefish maximum growth in length occurred in the first year of life. Growth characteristics of the Lake Erie population showed significant differences from those of Lakes Huron and Ontario.

Miller (1947) indicated the effects that varying intensities of fishing may have on whitefish populations. In one Alberta Lake, which was closed to commercial fishing for two years, the growth rate apparently did not change but the population did show an increase in average age. Another lake, subjected to heavy fishing, showed an accelerated growth rate along with decreased average age. The increased growth rate was enough to compensate for the decreased average age so that a hundred fish of the commercial catch, following the period of intensive fishing, weighed 12% more than 100 fish taken before the netting began. A further point in Miller's paper is that along with an increased growth rate and diminished average age in the heavily fished population, the age at the time of first spawning decreased so that, although younger fish were being caught,"........the spawning escapement was about the same."

Other points of interest in age studies are maximum weights and ages. A considerable amount of data concerning this point for whitefish was found in the literature and will be compared with data from Flathead Lake.

To demonstrate that fairly reliable mortality curves could be constructed from age frequency data, Ricker (1947) used previously published data from several unexploited whitefish populations.

Depth Distribution and Movements.

Koelz (1929), who relied in part on reports from fishermen, found evidences for seasonal movements both toward and away from shore in most of the Great Lakes. The movements into deeper water were found to coincide with the warming of the shoreward water in July and August. At other seasons whitefish were found to frequent shallower water - 45 feet or less. Evidence was presented which indicated that gill nets did not always effectively demonstrate the relative numbers of whitefish in shallow water because the nets may be seen by the fish. In such instances pound nets were apparently more effective in indicating concentrations of whitefish. Fishermen reported that very often only one of several pound nets in a neighborhood contained whitefish and that gill nets often caught all their whitefish in one small section of a gang. Koelz considered such reports as strong evidence for a 'schooling' tendency among whitefish.

Van Oosten (1938) pointed out that, "In the Great Lakes whitefish seldom occur in any large numbers at depths greater than 160 feet." In spring and early summer the fish concentrate at depths less than 60 feet, and migrated to deeper water, 80 to 110 feet in Lake Huron and 60 to 90 feet in Lake Michigan, in mid summer. In fall the whitefish returned to shallow water, probably remaining there until spring. Van Oosten added, "Whitefish are gregarious and travel in schools."

The most extensive tagging experiments which have been reported for the whitefish, are those of Smith and Van Oosten (1939). During a three year period 457 whitefish were tagged and 101 recaptures made. The large number of recaptures reflected the heavy pressure of the fishing industry. Most of the whitefish tended to migrate in a northerly direction from the tagging station on the west shore of Lake Michigan. Distances as great as 55 and 72 miles from point of release to recapture were recorded.

Kennedy (1940) found that a definite migration of several fish species, Coregonus clupeaformis among them, occurred in spring and early summer from a shallower, rapidly warming lake to a cooler, deeper lake.

Recently Rawson (1951) who worked in Great Slave Lake, a very deep Canadian lake, reported whitefish "common" down to 75 meters (246 feet) but "scarce" beyond that depth. No mention was made of seasonal migrations.

Some indication of the depth distribution of whitefish in Flathead Lake may be obtained from Elrod (1929) and Brunson and Newman (1951). The former indicated Coregonus ranged from 25 to 100 feet, and in Yellow Bay

Brunson and Newman took specimens at depths ranging from 30 to 100 feet with 50 to 80 feet the zone of maximal concentration. In the latter study sets between 100 and 200 were negative for whitefish.

Coefficients of Condition, "K", "C".

For a number of years American fishery workers have been using the ponderal index, or coefficient of condition, to express the relative plumpness or robustness of fish. While origin of 'C' and 'K' as applied to fishery work is obscure, both of these indices are "....based on the mathematical principle that if shape and relative density remain the same, the weight increases as the cube of the length. The formulae differ in the units of measure and whether standard fork, or total length is used." (Carlander, 1944). A constant is used to lessen the tendency for the values so obtained to be expressed as awkward decimals. Thus:

$$K = \frac{W(\text{in gms.}) \times 100{,}000}{L^3 \text{ (in millimeters)}}$$

and

$$\frac{W(\text{in lbs.} \times 100{,}000}{L^3 \text{ (in inches)}}$$

Criticisms of the coefficient of condition include those of Tester (1940), Kesteven (1947) and LeCren (1951). These will be considered in the discussion of 'Age and Condition.'

A number of papers using 'K' with reference to the lake whitefish appear in the literature. Hile and Deason (1934), Van Oosten (1938), Van Oosten and Deason (1938), Carlander (1944) and Van Oosten and Hile (1947) all have presented data for the condition of whitefish in the Great Lakes and near-by waters. As a note of caution, results should be considered in the light of size, age, season, and sex as well as environment.

Food-taking.

Carl Hubbs examined the stomachs of 160 whitefish taken from one location in Lake Huron. All collections were made in the fall of the year. The results, which were summarized by Koelz (1929), revealed that *Pontoporeia* constituted the bulk of the diet and was supplemented in almost every case by small molluscs, such as *Sphaerium* and *Amnicola*. Chironomid larvae also were taken frequently. Trichopteran larvae, bryozoan statoblasts, adult land insects, Corixidae and fish (*Cottus franklini*) were listed as "occasionally ingested." A collection of 15 stomachs from another area showed the burrowing mayfly, *Hexagenia*, to be the dominant food item. No itemized quantitative data were presented.

Bajkov (1930) found that whitefish fry in hatchery rearing troughs had eaten mostly Cladocera, Copepoda and immature Chironomidae. Whitefish in their second year were found to feed mostly on bottom fauna - Chironomid larvae, amphipods, and small molluscs, with *Pisidium* and *Amnicola* predominating. Food items were listed as percentages of the total food present in each stomach. No volumetric data were presented. The sample of fish in their second year was apparently taken from only one location. No attempt to demonstrate a seasonal feeding pattern was made. Adult whitefish showed no qualitative change in diet with increased age. Adult food consisted mainly of Amphipoda, Chironomid larvae, *Hexagenia limbata*, Phryganeidae and small molluscs. Although *Chara* and *Cladophora* were found in some of the stomachs, Bajkov considered them chance foods which were not a part of the diet. However, no proof was presented that the ingested plant material was not utilizable. Seasonal food shifts and variations in diet from lake to lake were treated superficially. The long-nose sucker, *Catostomus catostomus* was mentioned as a competitor to whitefish for food in Manitoban lakes. This species is present in Flathead Lake.

In the same paper (Bajkov, 1930), it was suggested that adult whitefish in Manitoban lakes consumed about 10 grams of food daily. It is likely however, that such factors as variable digestion rates, which are probably influenced by water temperature, leave the figure open to criticism.

Hart (1930) found that whitefish fry from Lakes Ontario, Nipigon, and Superior fed mainly on Cladocera, Copepoda and Chironomid larvae and pupae.

Hart (1931b) reported the chief food items of adult whitefish in Ontario lakes to be amphipods, molluscs and insect larvae. The increased importance of insect larvae as food items in shallow lakes was considered as evidence against selection in food-taking. In Shakespeare Island Lake, whitefish through age class IV were found to take considerable amounts of plankton. Little food was taken during the spawning season, but some evidence for winter feeding by whitefish was found. Competition for food with the long-nose sucker, Catostomus catostomus, was dismissed as being negligible in Lake Nipigon.

A good example of misuse of the words "feeding habits" may be found in the work of Van Oosten and Deason (1938). During a study of the spawning whitefish of Lake Champlain, 141 stomachs were collected from seined whitefish. Of these, only 20 contained food, hardly enough to discuss "food habits." The data did, however, suggest the limited feeding activity of ripening whitefish.

McHugh (1939), who reported on the examination of 55 stomachs of lake whitefish taken in Okanagan Lake, British Columbia, indicated that a wide variety of food items were taken. Data for individual food items were based on estimates of percentages of each item in the total stomach contents. The collections were made during July and August of one year and September and October of another year. Plant materials were recorded, the author apparently considering them as food items.

Rawson (1951) estimated that in Great Slave Lake amphipods and molluscs made up 90% of the food of the whitefish. Microplankters were not found to be an important dietary constituent. Whitefish were themselves an important part of the food web of the lake, inasmuch as lake trout were found to feed upon the whitefish. That lake trout feed to some extent on whitefish was also indicated by Van Oosten (1944).

The only previous study of the food of Coregonus in Flathead Lake, was that of Brunson and Newman (1951) who examined the stomachs of 71 whitefish from Yellow Bay. All material was collected during the summers of 1948 and 1949. Food varying in amount from a trace in some to 4.0 cc. in another was found in 35 stomachs. Food-taking was not correlated with size except for mention of the absence of Ostracods in all of the stomachs except that of the smallest specimen, a 37 gram whitefish. Evidence for Chironomidae as being the most important summer food item, with molluscs second, was presented. Water mites, though of frequent occurrence, were with two exceptions, of negligible volume. Cladocera and Copepoda were also frequently present, the genus Leptodora being found in 10 of the stomachs. Chaetophora sp. was the alga most often found.

Parasites.

The Parasite Triaenophorus found in the plerocercoid stage in the flesh of lake whitefish as well as other coregonids of Canadian lakes has been studied by Nicholson (1932), Newton (1933) and more recently by Miller (1946). The final host of the several species of Triaenophorus studied was found to be the pike, Esox lucius, which is not known to be present in Flathead Lake.

The sea lamprey, Petromyzon marinus, the subject of much investigation in the Great Lakes region because of its damage to many of the fish species there, is not known to be present in Flathead Lake.

THE SAMPLE

Sites of the Collections.

One of the distinct weaknesses noted in the literature was that many workers had the tendency to describe the characteristics of whitefish populations in extensive bodies of water on the basis of a few large collections of fish taken from one location. Although it was not feasible to sample intensively the whitefish population in all of Flathead Lake, an effort was made to reduce to a minimum any inherent errors resulting from collecting in only one area. Therefore, two bays, of decidedly different physical and biological characteristics, were sampled intensively, and additional collections were made in other parts of the lake to supply supplementary data. It was thought that if any variation occurred in food-taking, age composition, coefficient of condition and other characteristics of the populations within Flathead Lake, it would be most evident in analysis of samples from two dissimilar habitats.

One area chosen for intensive sampling was Yellow Bay (figure 1), site of the Montana State University Biological Station. Yellow Bay, one of the several, relatively small, deep bays of the northern part of Flathead Lake, is located midway along the east shore of the lake. Soundings indicate a maximum depth of over 50 meters near the mouth of the bay. A 'tongue' of the profundal zone of the open lake extends northward into the bay. The bottom on the east side of the bay rises gradually and passes from mud in the deep area to small stones and gravel in the littoral zone. The open lake forms most of the western boundary of the bay, but a bed-rock peninsula extends from the northern boundary southward across one third of the mouth of the bay. This formation characterizes the western shore of the bay as a series of precipitous rocky ledges. Continuing south from this peninsula, the bed-rock outcropping is strewn with large boulders, which are replaced successively by stone, gravel and finally mud bottom as the depth increases. Relatively strong currents, sometimes clockwise and at other times counterclockwise, and three small streams which enter the bay are additional physical features. Except for a brief period in late summer when a few potomogetons are found near the Biological Station dock, very little vegetation is found in the bay. A small part of the mud bottom of the inner bay supports a sparce growth of Chara. As whitefish movement around the south point of the peninsula was suspected, a large number of collections were made in that area.

Intensive collections were also made in Polson Bay (figure 2), a large shallow bay, located at the extreme

Figure 1. Aerial view of Yellow Bay (north at top of photograph).

Figure 2. General view of Polson Bay (looking northwest).

southern end of the lake and some 10 miles distant from Yellow Bay. The bottom of Polson Bay was found to be mostly a <u>Chara</u> covered ooze. However, shoreward areas, especially to the south and east, support a relatively heavy growth of submerged and aquatic plants. The Flathead River, which drains Flathead Lake, exits from the southwest corner of the bay at the city of Polson. Soundings made during the time of collections indicated the maximum depth (high water) of the bay to be about 6½ meters. The shoreward areas rise gradually, and during low water, temporary beaches up to 125 yards wide are common. The fluctuating water level of the entire lake undoubtedly has some effect on its productivity. The lake level is about 10 feet higher in late June than in early February. Preliminary surveys of the quantitative and qualitative benthos and plankton of both Yellow and Polson Bays had indicated the relatively greater productivity of the latter.

A second general weakness of previous whitefish studies has been the lack of comparative seasonal collections. In this investigation at least one collection was made in Yellow Bay during every month from May, 1951, through November, 1952, with the exception of the months of September, 1951, and January, 1952. The collections from Polson Bay were made in June, 1951, and from April to August, 1952. Sets in other parts of the lake were made at various times from May, 1951, to October, 1952. However, most of the fall and winter data were from Yellow Bay. A summary of collecting sites and times at which collections were made, will be found in the appendix of this paper. Reference to these tables will be made from time to time.

Types of Fishing Gear Employed.

Choice of fishing gear is one of the most vexing problems of fishery investigations. No one kind of net has been found to be entirely suitable. In the Great Lakes, data often are taken from whitefish captured in a number of different kinds of commercial gear - deep and shallow water trap nets, pound nets and large and small mesh gill nets (Van Oosten and Hile, 1947). Careful attention must be paid to determining variation in the results which might be caused by the type of collecting device used.

Where collections are made by the investigator rather than commercial fishermen, experimental gill nets are usually used. Mesh sizes employed in experimental gill netting vary with the species being studied. In past whitefish investigations gangs of nets, which had mesh sizes ranging from 1½ to 5½ inches stretch measure (3/4 to 2 3/4 inches square measure) have been used.

Hart (1932) used a gang of eleven gill nets. Each net was 50 yards long and was composed entirely of one mesh size. To obtain a graded series of mesh sizes Hart used the eleven nets in a gang of successively increasing mesh sizes, starting at 1½ inches stretch measure in the smallest net and increasing to 5 inches in the largest net. The intervals between mesh sizes of successive nets were ¼ to ½ inch.

Rawson (1951), who sampled the entire fish population of Great Slave Lake, used six nets, each of which was 50 yards long. The mesh size of the smallest net in Rawson's "standard gang" was 1½ inches stretch measure. Succeeding nets had meshes which measured 2, 3, 4, 5 and 5½ inches respectively. Choice of 1½ inch mesh as the smallest mesh was made because the young of most of the species were taken in considerable numbers with this size mesh whereas smaller meshes, even though made up of very fine thread, were relatively inefficient. Rawson also found very little difference in the length range of whitefish caught in the 5 inch mesh compared to the length of whitefish taken in the 5½ inch mesh. The great amount of overlapping in lengths of whitefish taken in the successively larger meshes, from 1½ to 5½ inches, suggested no need for introducing a larger number of mesh sizes.

With one exception the gill nets used in this investigation differed from those of Hart and Rawson in that each net was composed of a series of graded meshes, rather than one size of mesh. Specifications of the nets used are given in table III. The number of linear feet of each mesh size set during this study are shown in table IV.

One of the chief disadvantages of gill netting fish is that they are usually killed in the gilling process. To obtain large numbers of live fish some kind of trapping device must be employed. Inasmuch as it was impossible to obtain deep water trap gear it was decided to attempt capture of whitefish by use of fyke nets. Although it was known that in the Great Lakes the fyke net had not proved an effective whitefish trap, the desirability of obtaining some idea of movements of whitefish in Flathead Lake through recapture of tagged specimens prompted trapping by fyke nets. All of the fyke nets used in this experiment were manufactured by the Linen Thread Company, San Francisco, California. The diameter of the largest hoop in each net was six feet and each net contained two 20 foot leads of 3, 4, and 5 inch mesh (square measure). The fyke net sets, all made during July and August, 1952, are summarized in table V.

During the summer of 1951 several fyke nets were set in Yellow Bay in connection with another problem. No lake whitefish were taken in these nets. However, as the fyke nets could be set only in locations where gill netting had previously revealed little whitefish activity, it was decided to attempt trapping whitefish in Polson Bay. The first fyke net was set on July 16 and when pulled on July 18 contained four fish, one of them a lake whitefish. This

TABLE III

SPECIFICATIONS OF GILL NETS USED

Net designation	Number of feet and size of mesh (square measure) ** 3/4"	** 1"	** 1¼"	** 1½"	** 1 3/4"	** 2"	** 2½"	** 3"	** 4"	Total* length (feet)	Depth (feet)	Material	Manufacturer or source
A		30	30	30		30		30		150	6	Linen	Adams Net and Twine Co.
B		30	30	30		30		30		150	6	Linen	Linen Thread Co.
C		30	30	30		30		30		150	6	Linen	Linen Thread Co.
D	25	25	25	25		25		25		150	5	Linen	State Fish and Game Dept.
E		30	30	30		30		30		150	6	Linen	Adams Net and Twine Co.
F					150					150	6	Linen	State Fish and Game Dept.
150 x 12			30		30		30	30	30	150	12	Linen	Adams Net and Twine Co.
300 x 12			60		60		60	60	60	300	12	Linen	Linen Thread Co.

*Factory measure
**Factory measure checked by writer

TABLE IV

NUMBER OF LINEAR FEET OF EACH MESH*

Net designation	3/4"	1"	1¼"	1½"	1 3/4"	2"	2½"	3"	4"	Totals
A		1170	1170	1170		1170		1170		5850
B		1170	1170	1170		1170		1170		5850
C		1200	1200	1200		1200		1200		6000
D	900	900	900	900		900		900		5400
E		990	990	990		990		990		4950
Total	900	5430	5430	5430		5430		5430		
300 x 12			900		900		900	900	900	4500
150 x 12			390		390		390	390	390	1950
Total			1290		1290		1290	1290	1290	
Grand Total										34,500

*1650 feet of net 'F,' 1 3/4 inch not included.

5400 feet of net having no letter designation not included.

TABLE V

SUMMARY OF FYKE NET SETS IN POLSON BAY, 1952

Set number	Net designation	Date set	Date pulled	Catch summary					
				Coregonus clupeaformis	Prosopium williamsoni	Catostomus catostomus	Catostomus macrocheilus	Ptychocheilus oregonense	Mylocheilus caurinum
54-52	1	July 16	July 18	1		1	1	1	
56-52	1	July 18	July 23			1	4	1	
57-52	2	July 23	July 26			1	3	2	
58-52	3	July 23	July 26				1		
59-52	1	July 23	July 26						
63-52	1	July 26	Aug. 3		1		2		
64-52	2	July 26	Aug. 3			5	8		
65-52	3	July 26	Aug. 3			3	2		
69-52	1	Aug. 3	Aug. 13						
70-52	2	Aug. 3	Aug. 13						1
71-52	3	Aug. 3	Aug. 13			1	3		
			Totals	1	1	12	24	4	1

fish was released after being marked with a Peterson disk below the dorsal fin. The tagged whitefish appeared to be in good condition at the time of release.

This slight encouragement resulted in two more fyke nets being set in the vicinity of the first. The leads and open mouths of the second and third nets were placed in different directions from each other and from the first net. No more lake whitefish were captured during the succeeding weeks. The apparent decrease in the number of whitefish in Polson Bay in late July and early August may have been partially responsible for this lack of success. However, the numbers of whitefish taken by gill nets at the same site and the same time during the early part of the experiment indicated that the fyke nets were not an effective gear for live capturing lake whitefish during the summer months. It is possible that longer leads than those used might have increased the efficiency of the fyke nets as whitefish traps. Thus the data in this paper are derived almost exclusively from experimental gill net collections.

Relation of Size Classes to Mesh Size.

Gill-netted collections of fish rarely, if ever, represent random samples of the entire population studied. The greatest amount of selection tends to operate among the smallest fish. The small meshes, which are generally known to be inefficient, select only a few of these fish.

However, in samples taken with a graded series of successively increasing meshes, selection is not an important factor among the larger fish, provided that the successive mesh sizes increase with small enough increments to allow no gaps in the length frequencies of the individuals sampled. Thus, while any one mesh may be highly selective, successive mesh sizes take enough fish of lengths common to several mesh sizes as to eliminate gaps in the size range of the sample. The total catch curve for a gill netted sample normally consists of an ascending limb of small fish, a 'dome', and a descending limb of larger fish. It is the part of the collection in the descending limb which most nearly approaches a random sample.

In order to test for the presence of gaps in the length frequencies of the whitefish collected in this study, figures 3 and 4 have been prepared. The data presented in these tables are based on 513 of the 606 whitefish collected in this study. Inasmuch as no net designations were made for the first seventeen collections in 1951, the fish taken in those net settings were eliminated from this part of the analysis. In addition, all fish taken in net 'F', which was in poor repair and considered inefficient, were eliminated. All of the remaining fish were taken in gill nets plainly marked with a net letter designation. Each float in each net was numbered with waterproof ink.

Figure 3. Relation of mesh size of gill nets to the standard length of whitefish (6-foot nets).

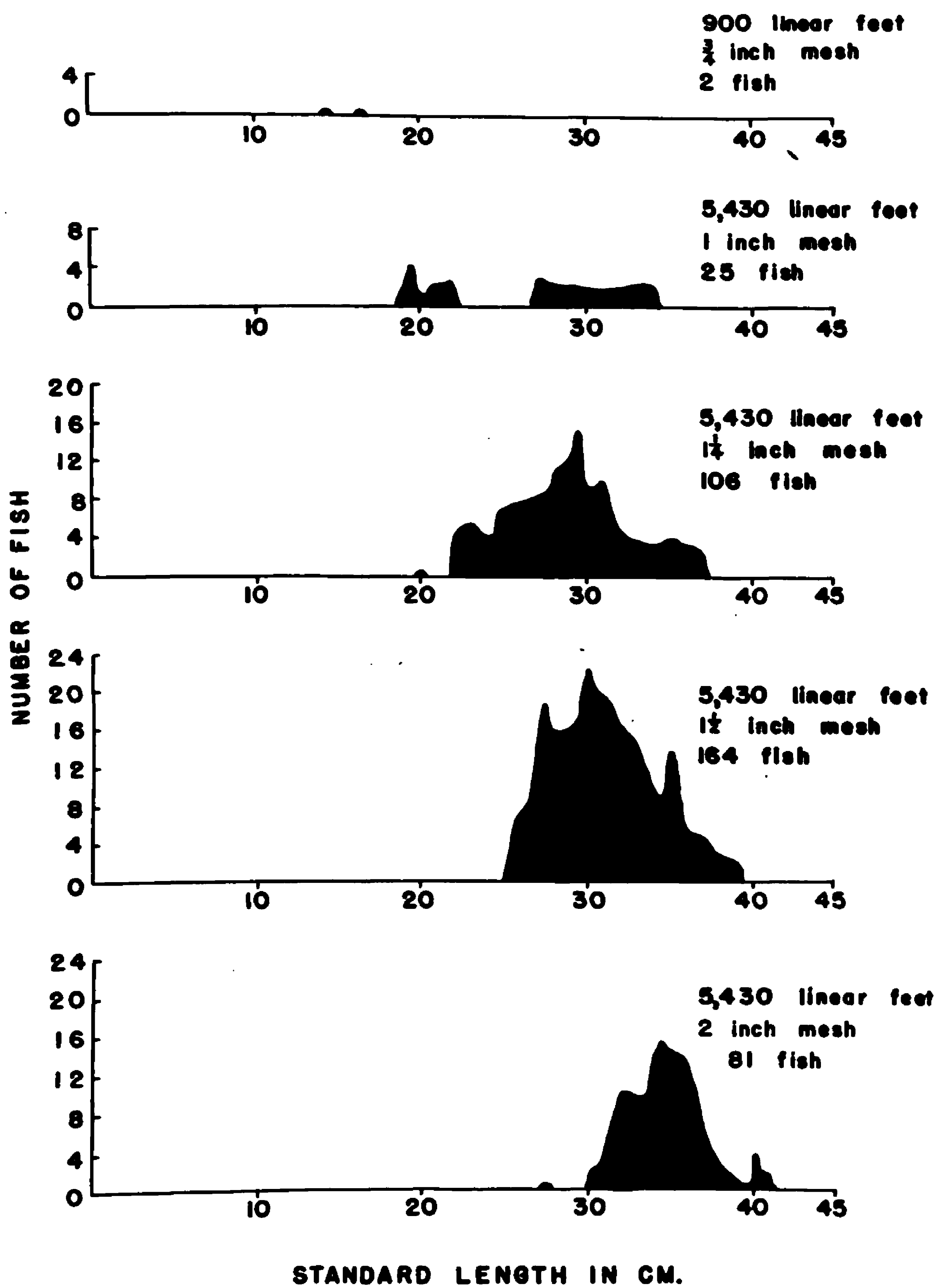
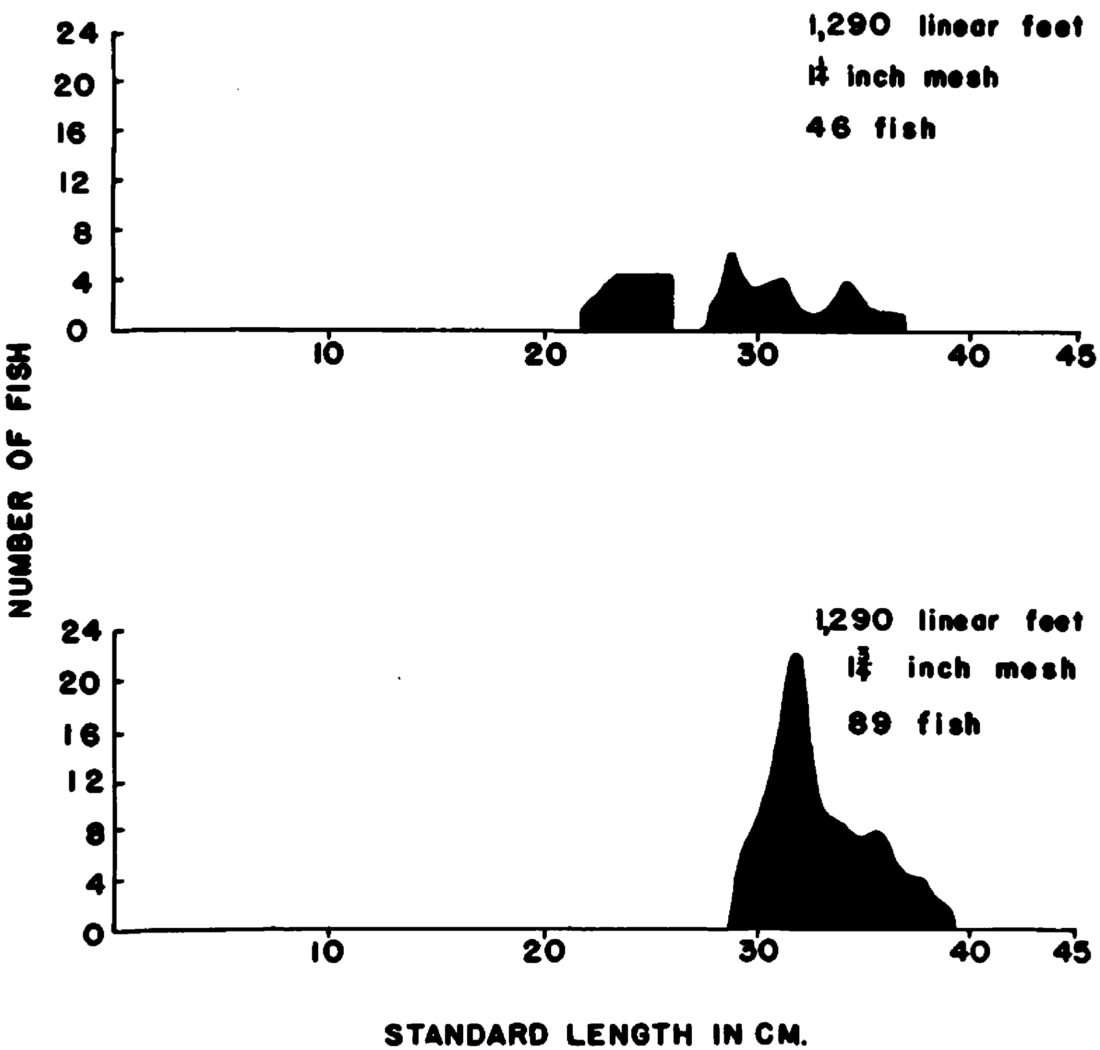

900 linear feet
¾ inch mesh
2 fish
5,430 linear feet
1 inch mesh
25 fish
5,430 linear feet
1¼ inch mesh
106 fish
5,430 linear feet
1½ inch mesh
164 fish
5,430 linear feet
2 inch mesh
81 fish
NUMBER OF FISH
STANDARD LENGTH IN CM.

Figure 4. Relation of the mesh size of gill nets to the standard length of whitefish (12-foot nets).


1,290 linear feet
1¼ inch mesh
46 fish
1,290 linear feet
1¾ inch mesh
89 fish
NUMBER OF FISH
STANDARD LENGTH IN CM.
24
20
16
12
8
4
0
10
20
30
40
45

The float number at which a fish was taken was recorded. Float numbers were checked against mesh size changes and in this way the relation of mesh size to the standard length of individual fish was determined.

The data used in preparation of figure 3 were obtained from fish collected in nets A, B, C, D, and E (table IV). Each of these nets stood six feet off of the bottom of the lake. The data used in figure 4 were obtained from nets which stood twelve feet off of the bottom of the lake. When the collections were initiated in 1951, it was felt that the gap between the 1½ and 2 inch mesh might be too large, and therefore the twelve foot nets which contained 1 3/4 inch mesh were frequently used. However, figure 3 reveals the large amount of overlapping of the standard lengths of whitefish taken in the successive meshes and suggests no need for introducing a larger number of mesh sizes.

One of the most striking features of figures 3 and 4 is the virtual absence of fish larger than 40 centimeters standard length. There is very little increase in maximum length of whitefish obtained in 2 inch mesh over those obtained in 1½ and 1 3/4 inch mesh. Rawson (1951) who worked in Great Slave Lake, took many whitefish of greater length in the same size meshes. No whitefish were taken in the 3 and 4 inch meshes in Flathead Lake and only one whitefish was taken in the 2½ inch mesh. This specimen measured 41.2 centimeters standard length. The absence of whitefish larger than 43 centimeters standard length in these collections is considered an indication of the scarcity of large whitefish in the collection areas and not as a selective factor inherent in the collecting gear.

Another feature of figures 3 and 4 is the tendency for relatively large whitefish to be taken in small meshes while small whitefish are seldom taken in large mesh. In figure 3 the 'normal' whitefish catch of the 1 inch mesh is represented by the fish in the 18 to 23 centimeter standard length range. The fish in the 27 to 35 centimeter range were caught by their maxillaries rather than being gilled.

Comparison of figures 3 and 4 seems to indicate that relative to the number of linear feet set, the 1 3/4 inch mesh took the largest number of whitefish. It must be remembered however, that the nets bearing 1 3/4 inch mesh stood 12 feet off of the bottom as against 6 feet for the nets in figure 3. There also was some tendency to 'set for whitefish' with the twelve foot nets, whereas the six foot nets were sometimes used in connection with other problems often in areas which brought negative whitefish results. It is probable that the 1½ and 1 3/4 inch meshes were about equally efficient in numbers of whitefish collected.

DEPTH DISTRIBUTION AND MOVEMENTS OF *COREGONUS*

Methods.

The gill nets were usually set at right angles to the shore with the smallest mesh of the inner net shoreward, although a number of the 1951 sets were made with the largest mesh of the inner net shoreward. The nets were set singly or in gangs of two to five nets. The twelve foot nets were not set in tandem with the six foot nets. One gallon glass jugs were used to mark the position of sets made in the profundal areas. Nets which ran from near shore outward were secured by means of a line tied to any convenient permanet object.

Special 'net set' cards were used in the field to record the set number, date, location, members of the party, net designation, whether the small mesh was in or out, the time at which the nets were set, wind direction, direction of the current (sub-surface observation), sky and water surface condition. Other conspicuous environmental features such as bottom type were also recorded. The same card was used to record conditions at the time the nets were pulled. Temperatures were recorded on special physico-chemical cards. At the time the nets were set, soundings at the inner and outer ends of the gang were made and recorded on the field note card. Profiles of the bottom of Yellow Bay were constructed from a hydrographic survey begun in 1951 and completed in 1952 by staff and students, the writer among them, of the Montana State University Biological Station.

It follows that since the inner and outer depths of the sets were known and the slope of the bottom of Yellow Bay could be constructed from the survey data, a fairly reliable picture of the depth distribution of whitefish in Yellow Bay could be obtained. The system of numbers used on the floats of each net allowed the depth at which each fish was taken to be plotted.

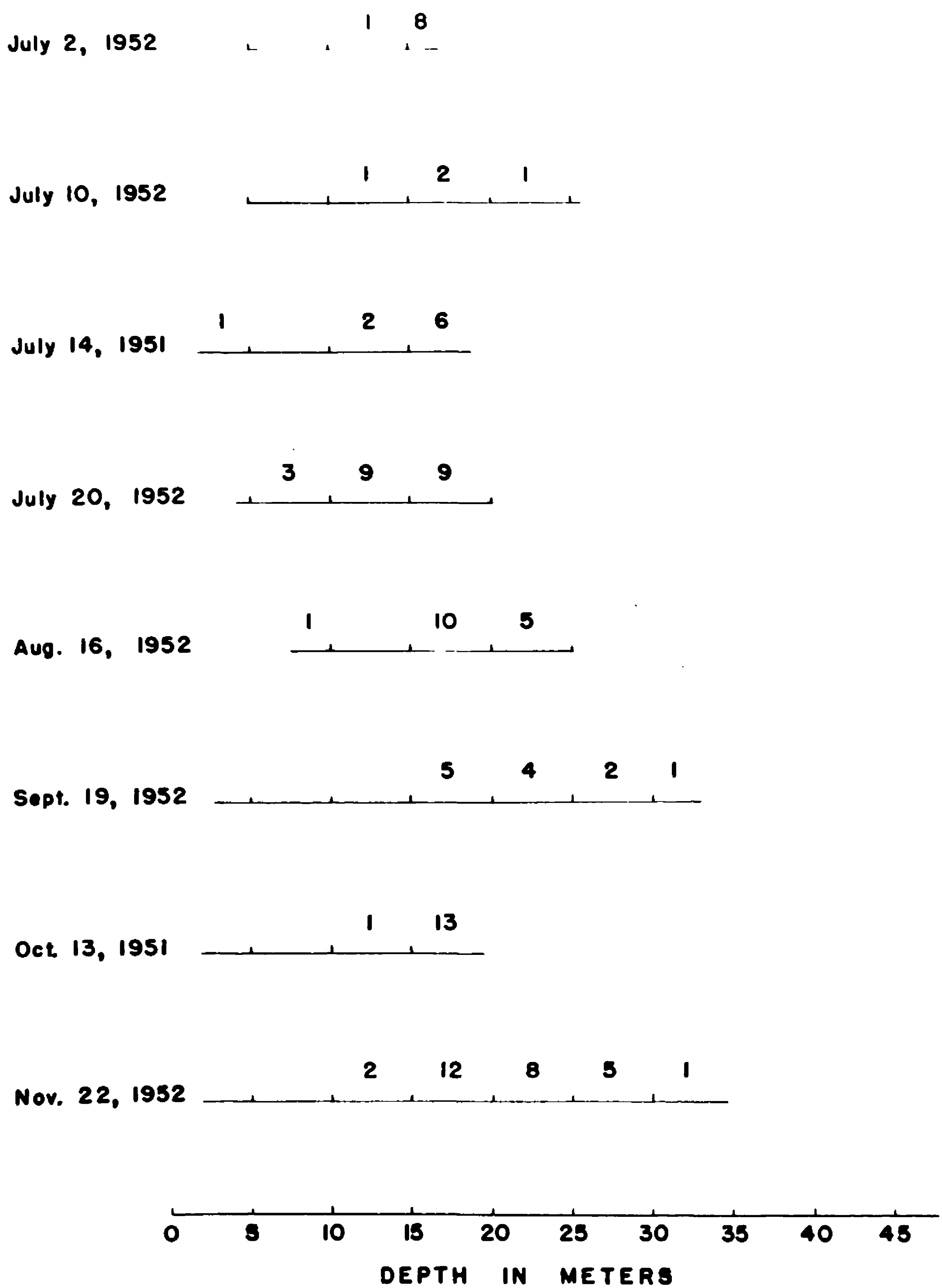
Depth was not a variable factor in Polson Bay. The depth at the inner and outer ends of the gangs usually differed from each other by a matter of inches (see apendix). The collections from other parts of Flathead Lake were too limited to merit detailed surveys of their hydrography.

Results and Discussion - Depth Distribution.

Inasmuch as a variable depth factor was operative in Yellow Bay, absent in Polson Bay, and little studied in other parts of Flathead Lake, most of the quantitative discussion of depth distribution will be limited to the Yellow Bay data.

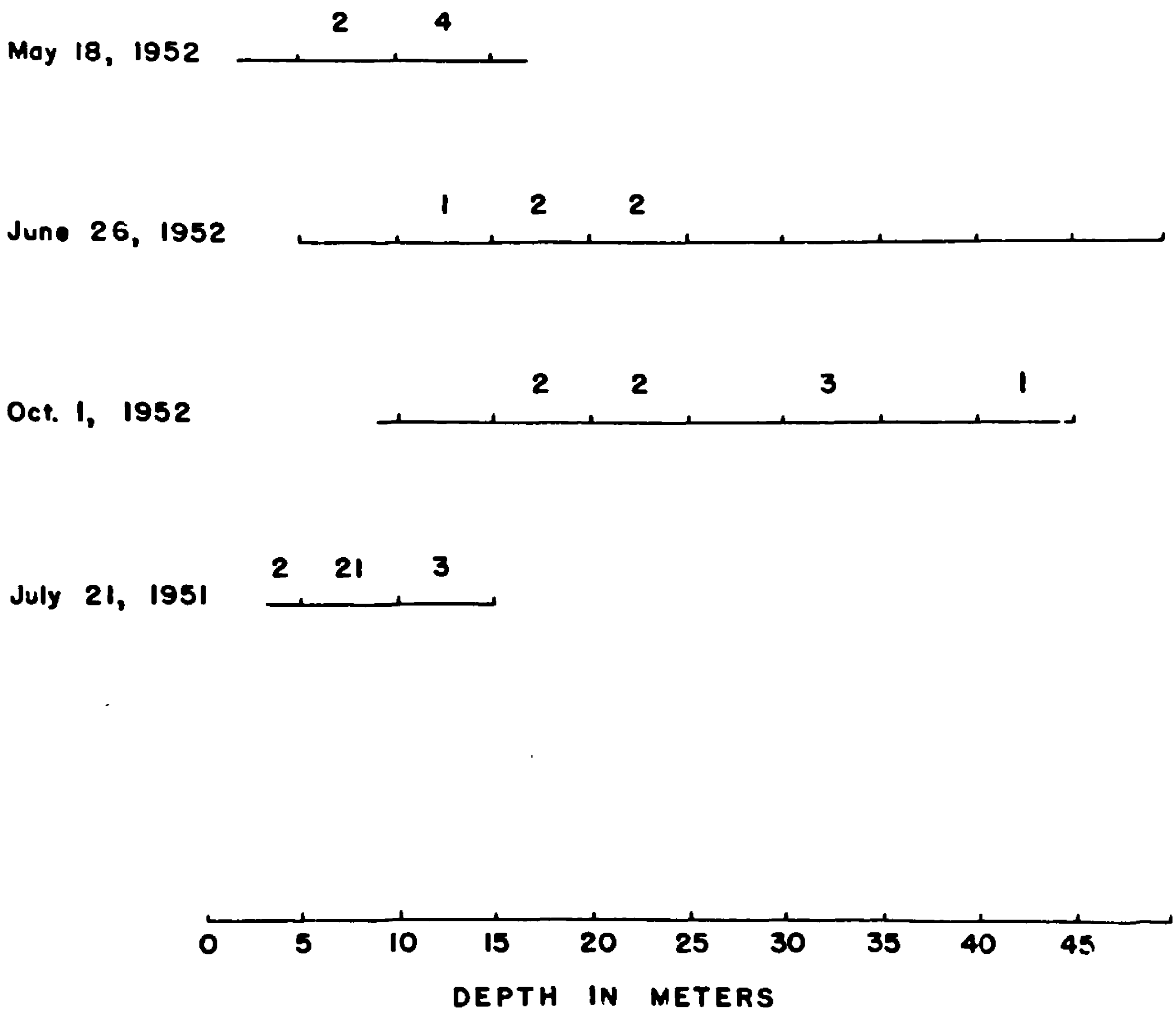
In order to obtain some indication of the zone of maximum concentration of whitefish in Yellow Bay, figures 5 and 6 have been prepared. In figure 5 the frequency distributions of whitefish taken in sets made south from

Figure 5. Depth distribution of whitefish taken south from Yellow Bay point. The horizontal lines represent the depth range in meters of the effective mesh on the dates indicated.



July 2, 1952
1 8
July 10, 1952
1 2 1
July 14, 1951
1 2 6
July 20, 1952
3 9 9
Aug. 16, 1952
1 10 5
Sept. 19, 1952
5 4 2 1
Oct. 13, 1951
1 13
Nov. 22, 1952
2 12 8 5 1
0 5 10 15 20 25 30 35 40 45
DEPTH IN METERS

Figure 6. Depth distribution of whitefish taken in Yellow Bay. The horizontal lines represent the depth range in meters of the effective mesh on the dates indicated. See text for location of these sets.



May 18, 1952
2 4
June 26, 1952
1 2 2
Oct. 1, 1952
2 2 3 1
July 21, 1951
2 21 3
0 5 10 15 20 25 30 35 40 45
DEPTH IN METERS

Yellow Bay point are arranged in 5 meter intervals. The dates of the collections are indicated at the left margins and the depth in meters at the bottom of the figure. The lines represent the ranges in depth of the 'effective' gill net meshes set on the dates enumerated. In cases where extensive amounts of 2½, 3 and 4 inch mesh were located at the outer end of a gang, those portions of the gang were eliminated in preparation of the figure. In these cases mesh size and not the depth factor could well have been the cause of the observed absence of whitefish. The collection made on July 2, 1952 is cited as an example of this practice. Soundings had indicated that the outer end of the gang was located in approximately 25 meters of water. However, profile analysis indicated that the outer end of the largest effective mesh (1 3/4 inches) was located in about 17 meters of water. The latter figure was used to represent the maximum depth of the July 2 collection.

Figure 6 was prepared in a manner similar to figure 5 except that the upper three collections plotted in the figure (May 18, June 26, and October 1, 1952) represent net settings made from the southeast shore northwestward in Yellow Bay. The collection of July 21, 1951 represents a special case to be discussed presently. More individual collection analyses are not presented, because many of the collections yielded only one or few specimens or the nets were set over too limited a depth range. The data presented, however, do give a graphic presentation of the concentration zone of whitefish in Yellow Bay. Figure 5 suggests that whitefish in the Yellow Bay point region concentrate in 15 to 25 or 30 meters of water in the period from August through November. The 10 meter contour is the approximate inner limit of large numbers of whitefish. This contention is supported by the large number of negative sets made at depths less than 10 meters during this same time interval. Sets which in July extended to 20 meters contained whitefish concentrations at the outer ends of the effective meshes, suggesting an outer depth limit beyond 20 meters for that period. It is probable that 15 to 30 meters is the zone of maximum whitefish activity on Yellow Bay point from July through November.

The sets from the southeast corner of Yellow Bay, figure 6, further support the 15 to 30 meter zone of concentration described from figure 5. The outer three 150 foot nets were negative in the June 26 collection. The three fish in the 30 to 35 meter interval in the October 1 collection were all taken at 30½ meters. The whitefish taken from 42 meters of water on October 1 was running deeper than any whitefish ever taken by Montana State University Biological Station workers since fishery investigations were resumed in 1947.

The July 21, 1951, collection apparently represents an exceptional case in which whitefish invaded the shallow littoral zone in Yellow Bay. The collection was made well within the enclosed northern end of Yellow Bay. The 120 feet of effective mesh of the inner net contained 23 whitefish. The 120 feet of effective mesh of the second net contained only two whitefish. One specimen was taken in the outer net (120 feet of effective mesh). It would appear that a large school of whitefish was running along the rock ledges which characterize the shoreward areas of the western enclosed part of Yellow Bay. Although whitefish were taken in the same general area at other times, they usually were taken at depths of 12 to 20 meters.

Negative evidence also is of value in depth analyses. A summary of the negative sets made in Yellow Bay during 1951 and 1952 is presented in table VI. Most of the sets were made in places where the effective meshes were outside the 15 to 30 meter zone of concentration. The depth data for Yellow Bay suggest no seasonal onshore, offshore migration of whitefish during the July through November period.

Results and Discussion - Movements.

The failure of the tagging experiment has, of course, severely limited the exploration of movements of the whitefish of Flathead Lake. The only record of a whitefish which

TABLE VI

SUMMARY OF NEGATIVE NET SETTINGS, YELLOW BAY 1951-1952*

Set number	Date	Location	Depth range (meters)	Bottom character
9-51	May 28, 1951	Point, west		Gravel
9-51	May 28, 1951	Point, south		Rocky ledge
12-51	June 30, 1951	Point, east	17-32	Mud
23-51	July 7, 1951	Inner Bay	10-16	Gravel, Mud
25-51	July 12, 1951	Point, east	20-32	Mud
27-51	July 13, 1951	Point, south	2-4	Rocky ledge
41-51	July 21, 1951	Biological Station dock	2.5-6	Detritus
42-51	July 21, 1951	Point, south	4-8	Rocky ledge
44-51	July 27, 1951	Point, south	2.5-6	Rocky ledge
49-51	Aug. 2, 1951	Point, east	28-32	Mud
51-51	Aug. 4, 1951	Point, south	2-5	Rocky ledge
52-51	Aug. 5, 1951	Point, south	2-5	Rocky ledge
8-52	April 20, 1952	Point, south	2-12	Rocky ledge
9-52	April 20, 1952	Inner Bay	3.5-10	Gravel
12-52	May 3, 1952	Point, south**	4-18	Rocky ledge
14-52	May 4, 1952	Inner Bay	5.5-18	Gravel
17-52	May 16, 1952	Point, south	3.5-19	Rocky ledge
34-52	June 16, 1952	Inner Bay	2-14	Gravel
66-52	August 9, 1952	Open Bay***	27.5-34	Mud
76-52	Oct. 1, 1952	Point, south	4-6	Rocky ledge

*Sets in which net 'F' was used excluded.
**Short daylight set.
***Daylight set.

may have left Flathead Lake in favor of a river environment is that of a single specimen taken by Frank Stefanich, Fisheries Biologist employed by the Montana State Department of Fish and Game (personal correspondence). The specimen was taken from the Whitefish River, Section 32, Range 21 W, Township 29 N on December 1, 1951. No other data concerning this fish are available at this writing except that a fish in this river could have come from Flathead Lake. It is interesting to note the presence of a lake whitefish in a river especially so near the time of spawning. Six lake whitefish were collected by the writer on June 23, 1952, from Flathead River 1½ miles below Polson.

Some indirect evidence for seasonal movement within Flathead Lake was obtained from the analysis of the Polson Bay collections made in June, July and August, 1952. These findings are summarized in table VII. Inasmuch as the analysis of age is to be discussed in detail in another part of this paper, age data are used here merely as one approach to the migration problem.

Four important facts should be kept in mind when examining table VII. First, there was a gradual increase in water temperature from a minimum of 12°C at the bottom (6 meters) and a maximum of 15°C at the surface of the bay on June 21, to a minimum of 21°C at the bottom and a maximum of 24° at the surface of the bay on August 14. Secondly,

TABLE VII

CHANGES IN AGE COMPOSITION, POLSON BAY, 1952

Date	Number of square feet of effective mesh*	Total fish	Number of fish per 100 square feet of effective mesh	Age composition						Water temperature (°C)	
				I	II	III	IV	V	VI	Min.	Max.
June 21	2,160	21	.97			3	7	10	1	12	15
July 7	2,160	42	1.95		2	10	20	6	2	14	16.5
July 16	600**	14	2.33	1		5	7	1		18	18.5
July 30	1,440	11	.76		6	4	1				
Aug. 14	2,040	3	.15	3						21	24

*1, 1¼, 1½, 1 3/4, 2 inches (squaremeasure).

**Set for two nights; all other sets pulled after one night.

the number of fish per 100 square feet of effective mesh dropped sharply after July 16. Thirdly, the age composition of the catch changed radically between June 21 and August 14 in spite of the fact that the largest effective mesh used on June 21 was 1 3/4 inches and on August 14 it was 2 inches. Lastly, all of the collections were made at the same general site on Chara covered mud bottom. Apparently the older whitefish left Polson Bay in the last part of July and early August.

AGE AND CONDITION

Methods.

All specimens were weighed and measured when fresh. Standard and total lengths were taken to the nearest millimeter on a specially constructed fish measuring board. Weights were taken to the nearest gram on a beam balance. A record card was prepared for each fish. A fish number, the net set number, date and location of the set were recorded. In addition to the length and weight data, sex, condition of the gonads and whether stomach contents were present and saved were recorded. Scale samples (10 to 12 scales) were taken from the left side of the body just above the lateral line and below the anterior edge of the dorsal fin. A second scale sample was taken on the dorsal side of the fish just posterior to the dorsal fin. The scale samples were placed in individual paper envelopes numbered in accordance with the fish number. Care was taken to avoid introducing 'wild' scales into the sample. No scales samples were taken from seven of the 1951 collections. However, at no time was there a failure to take a scale sample from a large fish.

Scales were cleaned in water and mounted on glass slides in a glycerine gelatine mixture. No less than three, and usually four, scales were mounted from each fish.

Ages were determined by the scale method of Van Oosten (1923), who demonstrated the validity of aging whitefish by this method. The annuli of whitefish scales are best marked off from each other by differences in the angle of formation of the circuli for each successive year. The circuli of whitefish tend to be laid down close together as each season of retarded growth approaches. Scales were read with the aid of a binocular dissecting microscope. All scale preparations were read at least twice. No comparison between the results of the first and second readings, made several weeks apart, was made until after the latter readings had been recorded. If the second reading did not agree with the first, more scales from the sample were mounted and read. If differences in the age determinations could not be resolved the specimen was not considered in the age study. In all, ages were determined for 507 whitefish.

The coefficients of condition, 'K', were calculated from the formula:

$$K = \frac{W\ 100{,}000}{L^3}$$

in which 100,000 is a constant used to avoid awkward decimals in the results and 'W' and 'L' are weights in grams and standard lengths in millimeters, respectively.

The length-weight regression lines (figures 7 and 8) were obtained from the logarithms of the lengths and weights of 189 specimens collected in Yellow and Polson Bays during the summer of 1952.

Results and Discussion - Time of Annulus Formation.

A prime consideration in any discussion of ages of fish determined from seasonal collections is the time that the new annuli are formed. Without a knowledge of the time of annulus formation significant errors in estimates of age composition may be made.

It was necessary to employ a series of scales collected over a period of several months in order to define the period of renewed growth of whitefish scales. The annuli of whitefish are characterized by crowded and packed circuli and by the angle at which new circuli are laid down. No annulus was considered complete until there were circuli beyond it. Inasmuch as collections of scales from several areas of Flathead Lake were available from both the spring of 1951 and of 1952, it was found possible to compare year, season and habitat for time of annulus formation.

Tables VIII and IX indicate the date, place, number of scale samples, the number of fish with the last annulus completed and the percentage of fish in each collection whose last annulus was completed by that date. Water temperatures are reported because they have been implicated by Van Oosten (1923) as a factor in the mechanism of growth resumption in whitefish. It has been shown by Van Oosten (1923) that a direct relation exists between growth in

TABLE VIII

TIME OF ANNULUS FORMATION 1952

Date	Location	Number of scale samples	Number with completed annulus	Per cent with completed annulus	Water Temp. (°C) Min.	Water Temp. (°C) Max.
May 16, 17, 18	Yellow Bay	40	0	0	6.0	9.0
May 17	Polson Bay	3	0	0		
June 1	Yellow Bay	2	0	0	6.5	12.0
June 1	Polson Bay	10	0	0		
June 16, 17	Yellow Bay	9	0	0	7.0	13.0
June 20	Yellow Bay	6	1	17		
June 21	Polson Bay	22	6	27	12.0	15.0
June 26	Yellow Bay	4	1	20	5.0	10.0
June 28	Polson Bay-Flathead River	6	3	50		
July 2	Yellow Bay	9	3	33	7.0	16.0
July 3	Flathead Delta	20	12	60	12.0	13.0
July 7	Polson Bay	36	26	72	14.0*	16.5
July 10	Yellow Bay	4	4	100	10.0	15.5
July 16	Polson Bay	13	12	92	18.0	18.5
July 20	Yellow Bay	21	21	100	10.0**	17.0

TABLE IX

TIME OF ANNULUS FORMATION 1951

Date	Location	Number of scale samples	Number with last completed annulus	Per cent with completed annulus	Water Temp (°C)	
					Min.	Max.
May 20	Yellow Bay	—	—	—		7.0
June 19, 20, 21	Yellow Bay	12	3	25		
June 23	Polson Bay	17	7	42		
June 28	Yellow Bay	3	3	100	7.0	15.0
July 5	Yellow Bay	3	2	67		
July 6	Melita Is.	9	6	67		
July 12, 14, 15	Yellow Bay	25	25	100		
July 22	Yellow Bay	—	—	—	9.0	22.0

length and scale growth. Therefore any factor affecting the former is reflected in the latter.

Inasmuch as collections were not initiated early enough in 1951 to determine when newly completed annuli first appeared on the scales, table VIII forms a more reliable basis for the discussion which follows.

With reference to table VIII, the collections prior to and including those of June 16 and 17, 1952, showed no newly completed annuli. However, there was some evidence of growth resumption on the margins of the scales collected in Yellow Bay on June 16 and 17. On June 20, one of six whitefish collected in Yellow Bay show a newly formed annulus with a few marginal circuli beyond. The following day, June 21, a collection of 22 whitefish from Polson Bay revealed that 6 of the 22 specimens had a completely formed annulus. Narrow bands of circuli beyond the last annulus characterized the scales of these fish. The percentages of fish which had completed annuli increased in the collections which followed, until annulus formation in all fish collected after July 16 appeared completed. Collections from Polson Bay revealed a slightly more rapid approach to the completion of annuli formation. However, one specimen collected in Polson Bay on July 16 did not appear to have resumed scale growth. All scale samples taken after July 20 showed the last annulus to be completed. The data for 1951 shown in table IX reveal a pattern similar to that shown in the 1952 collections. However, annulus formation appears to have started somewhat earlier and to have been completed about a week earlier in 1951 than in 1952.

Interpretation of the water temperature data is difficult because it is not known whether mean, maximum or minimum temperatures are most important. The period of time over which the various temperatures prevail may also be a factor. Temperatures were taken by means of either a thermophone or a maximum-minimum thermometer. The minimum temperatures are those of the lake bottom at 19 meters in Yellow Bay and 6 meters in Polson Bay. Little scale growth took place before a mean temperature of approximately 10° C (50° F) was reached. In the only previous work on annulus formation in whitefish, Van Oosten (1923) found that growth of the scales of aquarium whitefish resumed in March or April when the water entering the tanks reached 45° F. That the time of annulus formation may vary for two different species living in the same stream was recently demonstrated by Brown and Holton (1953), who found that annuli formed earlier in the rainbow trout than in the brook trout. Perhaps significantly, the mean water temperature was the same (47° C) when both species initiated scale grouwth. Beckman (1942) found annulus formation of several species of Michigan fish first became apparent when mean air temperatures reached 52° to 53° F and the majority of the specimens showed annuli completed at a mean temperature of 58° F. Annuli formed earlier in those years when mean air temperature reached 52° to 53° F at an earlier date. Inasmuch as water temperature lags behind mean air temperature during the early part of the year, it is probable that Michigan fish also initiate annulus formation at about 50° F or slightly less. In any case the data for Flathead Lake show that annuli were formed from about mid June to mid July in both 1951 and 1952.

Results and Discussion - Age and Size.

A startling contrast exists between the age composition of the present collection from Flathead Lake and the age composition of whitefish collected in other lakes. The contrast results mostly from the paucity of old fish in the collections from Flathead Lake. It is generally known that in a little exploited population, the proportion of older to younger individuals is very often greater than in heavily exploited populations. Therefore it is strange that the Flathead Lake collections reveal few old specimens. As previously discussed, the nets used in the collections did not appear to be selective against the largest fish, though it is possible that the presence of 2½ inch mesh in the collecting gear, would have increased somewhat the number of large individuals caught.

Only one specimen each in age classes VII and VIII was taken. These fish were both males and weighed 1034 and 803 grams respectively. The largest fish in the collections was a female of age class VI which weighed 1084 grams and measured 42.8 cm. standard length. This specimen was taken in 2½ inch mesh from Yellow Bay, June 21, 1952. The only whitefish taken in Flathead Lake since 1947 which was known to have exceeded the size of the largest individuals in the present collection was a 6 pound 1 ounce (2753 grams) specimen whose scales revealed it belonged to age class XII.

The specimen was collected by Dr. R. B. Brunson and H. W. Newman on July 26, 1950, near the Bird Islands just north of Polson Bay. Frequent collections were made in that area by the same workers and they report that no other whitefish were taken which approached the size of the one large individual. The smallest whitefish taken belonged to age class I; weighed 36 grams and measured 14.1 cm. The specimen was taken at a depth of 20 meters in Yellow Bay on July 5, 1951.

In other lakes, whitefish as large as 26 pounds have been reported. Bajkov (1930) states that the largest specimen taken during his investigation of whitefish in Manitoban Lakes weighed 16 pounds. However, a few years prior to the investigation, when commercial fishing intensity was considerably lower, specimens weighing 20 to 25 pounds "were not rare." Koelz (1929) indicated that Coregonus in the Great Lakes may weigh up to 20 pounds. Van Oosten (1938) stated that "The Great Lakes form reaches a weight of at least 26 pounds although the average weight is now about 3 pounds."

With reference to maximum age Van Oosten and Hile (1947) found Coregonus as old as age class XVI in their study of the heavily exploited Lake Erie whitefish. Individuals as old as XVII were taken in a spawning run collection from the little exploited whitefish population of Lake Champlain (Van Oosten and Deason, 1938). What factors contribute to the small age and size range in the present investigation are difficult to ascertain.

In addition to the possibility of gear selection, there are several other possible reasons for the narrow age range. One of these is the location of the collection sites. Another is the season of collection, since it was shown by Van Oosten (1938) that age composition may vary with the site and the time of collection. Table X summarizes the locations and times at which the 507 whitefish whose ages were determined were collected. The data show that older fish were not relatively any more frequent in collections from other parts of Flathead Lake than in Yellow or Polson Bays, the sites of intensive collections. In fact, a collection of twenty specimens taken from the area of the Flathead River delta on July 3, 1952 revealed no whitefish over age class IV. If older whitefish existed in any of the locations sampled, they were apparently in such low numbers that more intensive sampling would have to be made in order to reveal their presence. Table X also shows that the upper limit of the age range was apparently not extended by the season of collection.

There is the possibility that older whitefish leave Flathead Lake via the Flathead River at the northern end of the lake (exit by the lower Flathead River at the south end of the lake is blocked by Kerr dam). Inasmuch as the tagging experiment failed to materialize, movements outside of the lake remain an unknown factor.

A high mortality rate among the older fish may also be a factor of considerable importance in setting the upper limits of the observed age distribution. If such be the case, the factor or factors responsible are unknown to the writer. Certainly a predation factor does not seem probable, inasmuch as the predators would probably tend to strike the smaller, rather than the larger whitefish. Furthermore, the lake trout, Christivomer namaycush, known to take whitefish, is apparently not abundant and the dolly varden trout, Salvelinus malma, seldom takes lake whitefish (Brunson, unpublished). It is possible that the plankton diet (see section on food-taking) upon which whitefish must subsist for much of the year, will not maintain the older and larger whitefish. In any case the age range is relatively narrow for whitefish in Flathead Lake. Narrower ranges have seldom been found for whitefish populations sampled as intensively as this one has been.

As in other gill netted whitefish samples, no members of age class O were taken. Table X reveals that age class IV predominated in most of the 1952 collections and age class III predominated in most of the 1951 collections. Inasmuch as the same kind of gear was used in both years, it would appear that the dominance age class III in 1951 and of age class IV in 1952, reflects the success of the

TABLE X

SUMMARY OF AGE FREQUENCY DISTRIBUTION

Time of collection	Location	Age Class								
		I	II	III	IV	V	VI	VII	VIII	Totals
February 16, 1952	Yellow Bay				1	7	2			10
March 22–June 1, 1952	Yellow Bay		5	8	19	10	5		1	48
April 20–June 1, 1952	Polson Bay		4	3	9	5	3			24
June 19–August 12, 1951	Yellow Bay	1	13	29	22	9	2			76
June 16–August 16, 1952	Yellow Bay	3	4	23	42	16	1			89
June 23, 1951	Polson Bay		2	7	3	5				17
June 21–August 14, 1952	Polson Bay	4	8	22	37	14	3	1		89
July 6, 1951	Melita Island		3	5	1					9
June 24, 1952	Wild Horse Island			2	1					3
July 3, 1952	Flathead River Delta		5	6	9					20
July 14, 1952	Big Arm Bay				1					1
August 10, 1952	Below Wood's Bay				3					3
October 2, 1952	Bull Island	6	4	7	3	1	1			22
October 13, November 3, and November 24, 1951	Yellow Bay		4	12	6	7				29
September 19, October 1, November 22, 1952	Yellow Bay	3	4	25	26	7	2			67
	Totals	17	56	149	183	81	19	1	1	507

whitefish hatched in 1947 over those hatched in 1946 and 1948.

The Age-Length Relation.

Comparison of the frequency distributions of the summer collections from Polson and Yellow Bays (tables XI to XIII) reveal the similarity of the lengths (sexes combined) of the best represented age classes. Tables XI and XII indicate that very little difference existed between the standard lengths of age class III, IV and V of whitefish collected in Yellow Bay in 1951 and 1952. The small variation in lengths of these age classes supports the previous contention that the shift in dominance from age class III in 1951 to age class IV in 1952 reflected the relative abundance of the age classes in the two different years and was not the result of gear selection. Table XII indicates that whitefish in age classes III and IV taken in Polson Bay had greater standard lengths than fish of the same age classes collected during a similar period in Yellow Bay. However, the age composition for the two bays was quite similar and the observed differences could well be the result of the relatively better environment afforded whitefish in Polson Bay during the first part of the year (see section on food-taking).

Tables XI to XIII also demonstrate graphically the great amount of overlap in length ranges between the various

TABLE XI

FREQUENCY DISTRIBUTION OF CORECONUS (COLLECTED IN YELLOW BAY, JUNE 19 TO AUGUST 12, 1951) ACCORDING TO STANDARD LENGTH AND AGE CLASS

Standard length interval in mm.	Age class I	II	III	IV	V	VI	VII	Totals
140-149	1							1
150-159								
160-169								
170-179								
180-189								
190-199								
200-209		2						2
210-219		1						1
220-229		1						1
230-239		2	1					3
240-249		1						1
250-259		1	1					2
260-269								
270-279		3	3					6
280-289		1	5	3				9
290-299			7	3				10
300-309		1	3					4
310-319			2	2	1			5
320-329			1	3				4
330-339				4	2			6
340-349			3	4	2			9
350-359			3	2	2	1		8
360-369				1	1			2
370-379						1		1
380-389					1			1
390-399								
Totals	1	13	29	22	9	2		76
Mean length in mm.	145	248	302	324	348	364		
% of sample in each age class	1.32	17.11	38.15	28.95	11.84	2.63		

TABLE XII

FREQUENCY DISTRIBUTION OF CORSGONUS (COLLECTED IN YELLOW BAY, JUNE 16 TO AUGUST 16, 1952) ACCORDING TO STANDARD LENGTH AND AGE CLASS

Standard length interval in mm.	Age class I	II	III	IV	V	VI	VII	Totals
170-179	2							2
180-189	1							1
190-199								
200-209								
210-219								
220-229								
230-239								
240-249			1					1
250-259		2						2
260-269		2	4	1				7
270-279			1	1				2
280-289			2					2
290-299			2	1				3
300-309			4	5				9
310-319			3	14	2			19
320-329			4	10	1			15
330-339			1	2	4			7
340-349			1	5	1			7
350-359					3			3
360-369				2	3			5
370-379				1				1
380-389					1			1
390-399								
400-409					1			1
410-419								
420-429						1		1
Totals	3	4	23	42	16	1		89
Mean length in mm.	178	260	299	321	349	425		
% of sample in each age class	3.37	4.49	25.84	47.19	17.98	1.12		

TABLE XIII

FREQUENCY DISTRIBUTION OF CORECONUS COLLECTED IN POLSON BAY (JUNE 21 TO AUGUST 14, 1952) ACCORDING TO STANDARD LENGTH AND AGE CLASS

Standard length interval in mm.	Age class I	II	III	IV	V	VI	VII	Totals
170-179								
180-189	1							1
190-199	1							1
200-209								
210-219	2							2
220-229								
230-239								
240-249		1						1
250-259		2						2
260-269		1						1
270-279		4		1				5
280-289			4					4
290-299			3	1				4
300-309			3	3	1			7
310-319			3	5				8
320-329			2	10	3			15
330-339			3	2	3			8
340-349			3	4	1			8
350-359			1	4	1	2		8
360-369				5	2			7
370-379				2	3	1		6
380-389								
390-399								
400-409							1	1
410-419								
Totals	4	8	22	37	14	3	1	89
Mean length in mm.	202	265	315	333	345	361	415	
% of sample in each age class	4.49	8.99	24.72	41.57	15.73	3.37	1.12	

age classes. Although separation of age class I from all other age classes on the basis of size is possible during the summer, fall collections showed an overlap in standard lengths of age classes I and II.

Coefficient of Condition, 'K'.

The coefficient of condition, 'K', is widely used by American fishery workers. Whether the value so obtained represents a valid measure of physiological vigor, however, is questionable. Ease of calculation has resulted in the wide acceptance of 'condition factors' in management studies.

Kesteven (1947) noted that 'K' may vary with (1) the genetic capacity for being fatter, (2) seasonally with variations in available food and the favorability of the environment toward its use, (3) stages in the development of the gonads and (4) adjustments arising out of seasonal physiological changes or to permit changes of habit. Kesteven felt that changes in both volume and density must be considered in condition studies. Kesteven's critique was not supported by experimental work, however.

Recently, LeCren (1951) analyzed condition through an analysis of variance. Food, condition of the gonads and other factors were considered in the analysis. However, LeCren did not analyze variance in the specific gravity of his sample because all but demersal forms of fish utilize their swim bladder in adjusting their specific gravity to the environment. However the same worker (personal correspondence) says significantly that ".....perhaps the study of fat content (or 'flesh' density if it proves a good measure of fat content) may be more rewarding biologically than the study of condition factors."

Other factors such as the fat factor 'F' have also been used as an index of condition (Tester, 1940). The specific gravity method used in determining the fat factor is, however, refined enough for only very oily fish, such as cod and pilchard.

The data presented in this paper are given with full knowledge of their limited application to the physiological vigor of whitefish in Flathead Lake.

Table XIV indicates that 'K' varied little with the sex, habitat, or the year (1951 and 1952). However, a definite seasonal fluctuation occurred. An analysis of variance might have revealed whether food, sexual maturity or some other factor was responsible. It was observed that many of the older spawning fish had a very low 'K' value. The average 'K' for 9 spent whitefish collected in February and March was 1.27. The 'K' value for whitefish in Flathead Lake appears to drop somewhat in the fall, and be lowest in the spring. The highest 'K' values obtained, occurred in fish taken in the summer.

Table XV is arranged to show the relation of the standard length of whitefish in Flathead Lake to the

TABLE XIV

COEFFICIENT OF CONDITION 'K' ACCORDING TO SEX, HABITAT, SEASON AND YEAR

'K'	Yellow Bay May 4 to June 1, 1952		Polson Bay April 20 to June 1, 1952		Yellow Bay June 19-Aug. 12, 1951		Yellow Bay June 16-Aug. 16, 1952		Polson Bay June 17 to Aug. 14, 1952		Yellow Bay Oct. to Nov. 1951		Yellow Bay Sept to Nov., 1952	
Interval	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
.96-1.05			1									1		
1.06-1.15	1	1	1		1			1	1			3		
1.16-1.25	2	3	1			1					1		1	
1.26-1.35	11	10	2	3	4	4	3	4	5	7	2	6	5	3
1.36-1.45	4	5	2	6	7	7	15	16	13	10	4	2	13	12
1.46-1.55	3	2	3	3	10	12	22	17	16	17	4	5	11	7
1.56-1.65			2		10	12	6	5	4	8		1	1	3
1.66-1.75					4		2	1	2	3		1	1	
1.76-1.85					2				1					
1.86-1.95														
1.96-2.05					1									
Number in each sample	21	21	12	12	39	36	48	45	43	45	11	19	32	25
Arithmetic mean 'K'	1.32	1.33	1.37	1.38	1.53	1.49	1.49	1.47	1.47	1.49	1.40	1.37	1.44	1.45
Lowest 'K'	1.13	1.15	1.05	1.30	1.12	1.20	1.30	1.14	1.12	1.29	1.18	0.99	1.18	1.32
Highest 'K'	1.53	1.52	1.56	1.52	1.98	1.65	1.67	1.66	1.85	1.70	1.55	1.73	1.74	1.64

TABLE XV

THE RELATION OF THE COEFFICIENT OF CONDITION 'K' TO STANDARD LENGTH OF 185 COREGONUS, SEXES COMBINED, COLLECTED IN YELLOW AND POLSON BAYS FROM JUNE 16 TO AUGUST 16, 1952

Standard length interval in mm.	Number of fish per interval	Mean 'K' per interval	Standard length interval in mm.	Number of fish per interval	Mean 'K' per interval
170-179	2	1.40	300-309	16	1.47
180-189	2	1.59	310-319	24	1.52
190-199	1	1.53	320-329	32	1.52
200-209			330-339	16	1.50
210-219	1	1.67	340-349	14	1.47
220-229	2	1.45	350-359	13	1.46
230-239			360-369	11	1.47
240-249	2	1.48	370-379	8	1.35
250-259	6	1.47	380-389	2	1.21
260-269	7	1.47	390-399		
270-279	8	1.46	400-409	1	1.14
280-289	7	1.46	410-419	1	1.48
290-299	8	1.48	420-429	1	1.38

coefficient of condition. 'K' does not appear to vary significantly in whitefish between 240 and 370 mm. standard length. There is some tendency for fish above 370 mm. standard length to possess low 'K' values. The values obtained for the smallest fish (170-230 mm.) are probably biased by the collecting gear, which tends to select only the more robust members of the smaller size classes.

The Length-Weight Relationship.

In order to ascertain the relationship between length and weight, the lengths and weights of 99 whitefish collected during the summer of 1952 in Polson Bay and of 90 whitefish collected in Yellow Bay during the same period in 1952 were converted to logarithms. The regression values developed from the log data were tested for "significance" by means of the "T" test. It was found that the "null" hypothesis (i.e. that the observed difference is zero) could not be rejected even at the .05 level. Therefore, the seperate length-weight regression lines shown in figure 7 were combined. Figure 8 indicates the regression line developed from the combined samples.

The relationship between length and weight may be expressed by the equation:

$$W = aL^{x}$$

where 'W' is the logarithm of weight, 'L' is the logarithm of length, 'a' is a constant and 'x' is the exponent of

Figure 7. The length-weight relationship of whitefish collected in Yellow and Polson Bays. The line originating at the lower left represents the Yellow Bay sample. The line to the right of the Yellow Bay sample represents the length-weight regression line of the Polson Bay collection. (Both lines from fish collected from mid June to mid August, 1952). The crosses represent individual fish from Yellow Bay and the dots individual fish from Polson Bay. The calculated slope of the Polson Bay line is 3.45 and the log value of the constant 'a' is -2.53174. The calculated slope of the Yellow Bay line is 2.54 and the log value of the constant 'a' is -1.15514.

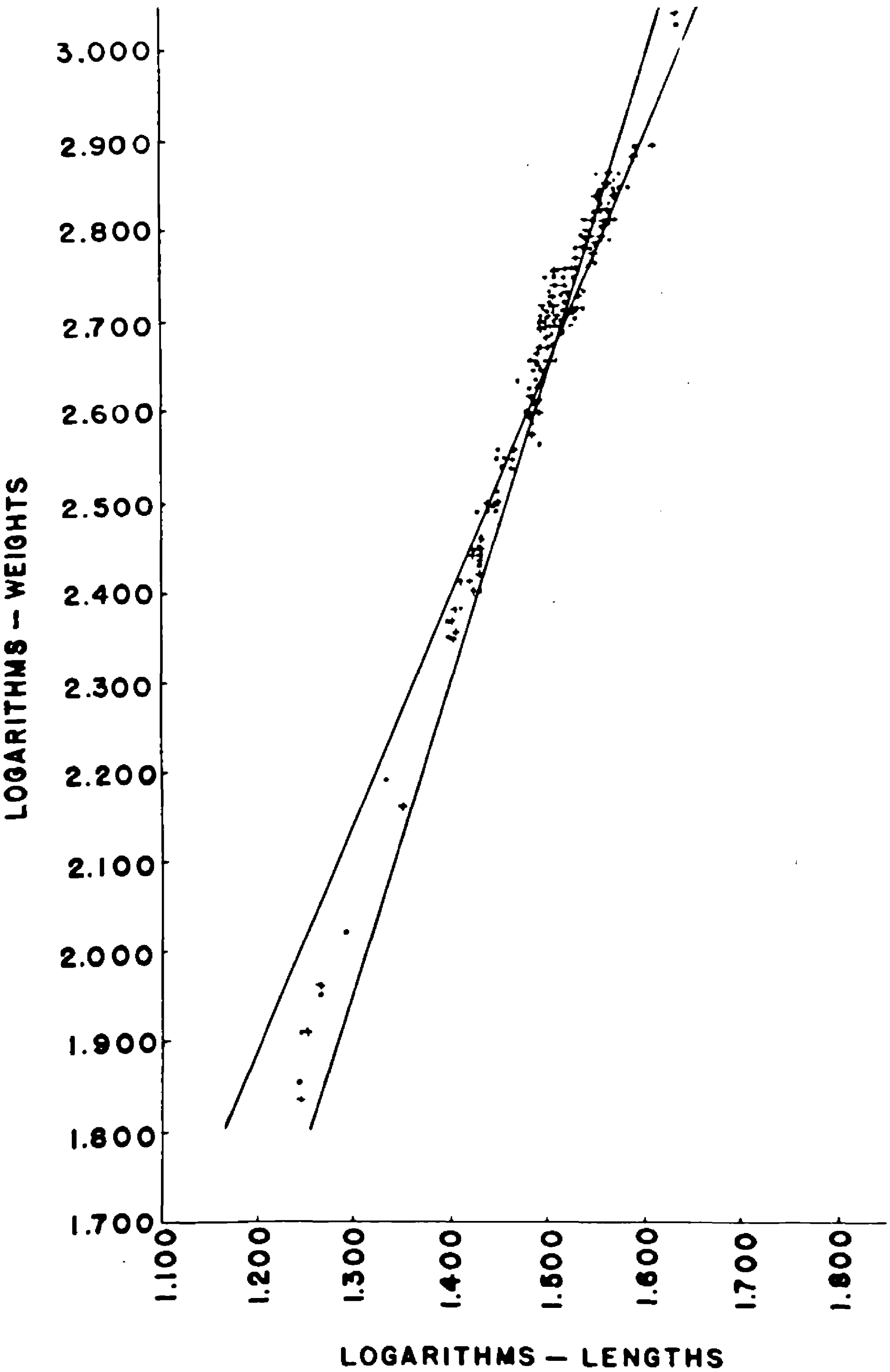
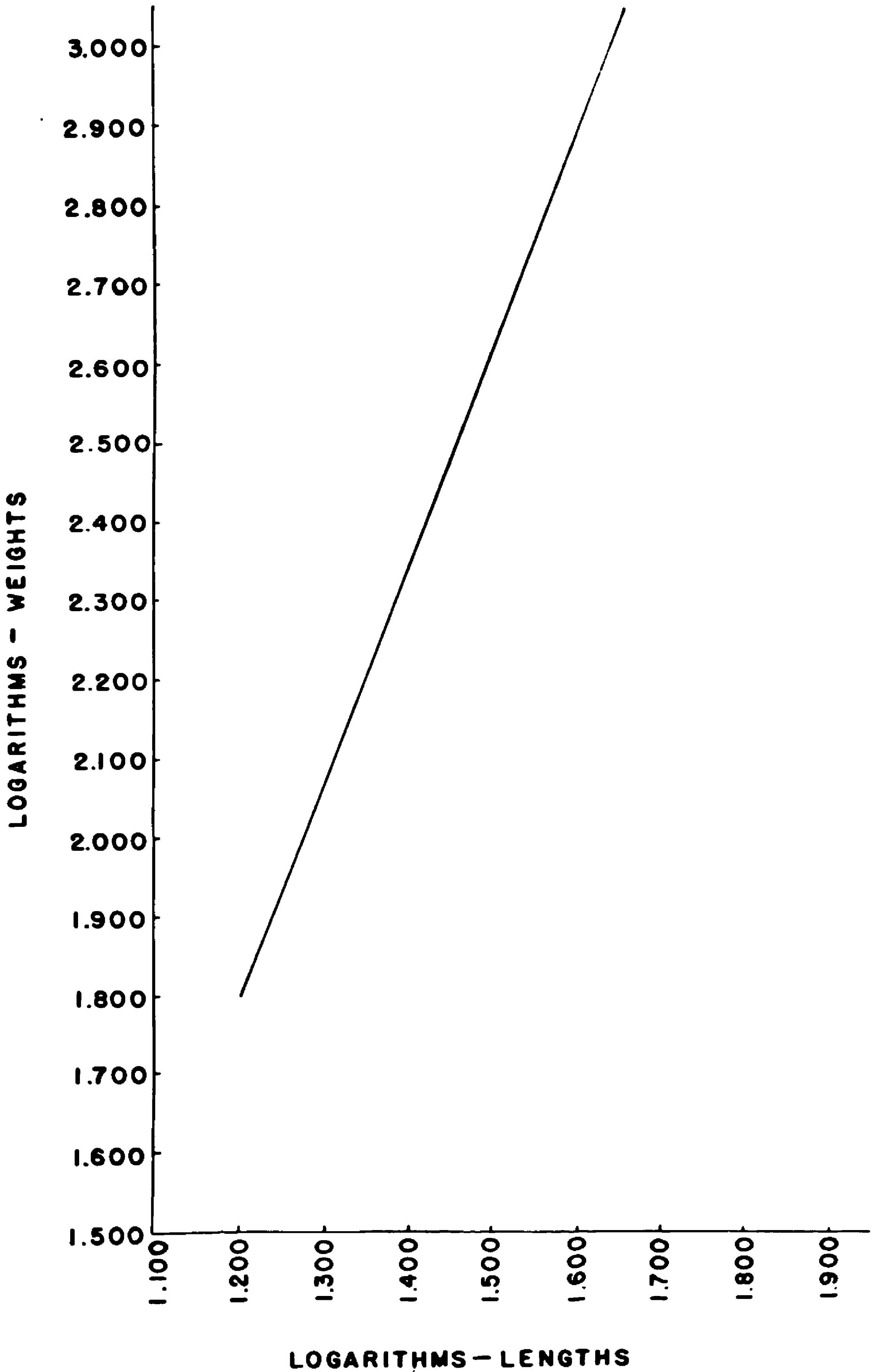

3.000
2.900
2.800
2.700
2.600
2.500
2.400
2.300
2.200
2.100
2.000
1.900
1.800
1.700
LOGARITHMS — WEIGHTS
1.100
1.200
1.300
1.400
1.500
1.600
1.700
1.800
LOGARITHMS — LENGTHS

Figure 8. Length- weight regression line of combined Yellow Bay and Polson Bay samples. The calculated slope of the line is 2.84 and the log value of the constant 'a' is -1.61612.



3.000
2.900
2.800
2.700
2.600
2.500
2.400
2.300
2.200
2.100
2.000
1.900
1.800
1.700
1.600
1.500
LOGARITHMS - WEIGHTS
1.100
1.200
1.300
1.400
1.500
1.600
1.700
1.800
1.900
LOGARITHMS — LENGTHS

length. The calculated value of 'x' for whitefish in Flathead Lake (combined sample) is 2.84. The log value of the constant 'a' is -1.61612. The significance of the similar length-weight relationships of the two samples is considered in the section on "Conclusions Concerning the Populations of *Coregonus* of Polson and Yellow Bays."

SPECIAL TOPICS

Discussion - Sex Ratios.

A summary of the sex ratios of whitefish collected in Yellow and Polson Bays is shown in table XVI. Only fish in age class III and above were used in preparation of the table because diagnosis of sex by observation of the gonads was possible for none of the members of age class I and only a part of the age class II fish. All of the data for the fall season were collected from Yellow Bay. Data from both Polson Bay and Yellow Bays were used to obtain the spring and summer ratios. The data for Yellow and Polson Bays were combined only after separate analyses for the two areas had been made. The combined sex ratios for age classes III to VI in Yellow and Polson Bays during the summer (mid June to mid August) were: Yellow Bay, 1951, 51.7% males to 48.3% females; Yellow Bay 1952, 54.3% males and 45.7% females; Polson Bay 1952, 46.7% males and 53.3% females. The slight numerical advantage of the females over the males in Polson Bay in 1952 was the result of the predominance of females (25 females to 10 males) in the age class IV catch from Polson Bay. There may have been some tendency for males of age class IV to move out of Polson Bay before the rest of the fish. The effect of sexual maturity and related factors also may have influenced the observed variation. The spring collections from Yellow

TABLE XVI

SEX RATIOS

Season of capture	Sex	Age group III	IV	V	VI	III-VI
Spring, 1952	Males percentage	60 (6)*	46.4 (13)	20 (3)	25 (2)	39.3 (24)
	Females percentage	40 (4)	53.6 (15)	80 (12)	75 (6)	60.7 (37)
Summer, 1951, 1952	Males percentage	65.7 (46)	40.8 (40)	50 (20)	50 (3)	50.9 (109)
	Females percentage	34.3 (24)	59.2 (58)	50 (20)	50 (3)	49.1 (105)
Fall, 1951, 1952	Males percentage	59.5 (22)	39.3 (11)	23.1 (3)	100 (2)	47.8 (38)
	Female percentage	40.5 (15)	60.7 (17)	76.9 (10)		52.2 (42)

*Number of fish employed in paranthesis.

and Polson Bays also showed similar overall sex ratios. Males made up only 37% of the total spring collection in Polson Bay and only 40.5% of the collection from Yellow Bay. The cause or causes responsible for this observed variation are unknown.

It is interesting to note that regardless of the season of collection males predominate in age class III and females in age class IV. Gear selection is probably not responsible for this difference because females were somewhat heavier and of slightly greater length in both age classes III and IV of the collections from Yellow and Polson Bays. The range of size for most of the fish in these two age classes was well within the size range effectively sampled by the nets (see tables XI, XII, XIII and figures 3 and 4). The differences in the sex ratios of these two age classes may reflect differential mortality rates for the sexes.

The overall sex ratios for whitefish collected in the summer and fall closely approximate those reported for whitefish in the Great Lakes (see table 2). The rather close approximation to a 50-50 sex ratio for the fall collections indicates the net sets were not made near the spawning ground (see table 2).

Discussion-Sexual Maturity.

Inasmuch as it must be conceded that gross examination of gonads for determining sexual maturity is a poor substitude for histological technique, the data on sexual maturity can offer only approximate results. Sexual maturity, as used in this report, refers to fish with active gonads. It is quite possible, of course, that a fish which spawns one year may skip a year or more before spawning again. To the knowledge of the writer, it has not been demonstrated that lake whitefish spawn on a two or three year cycle or, for that matter, even a one year cycle. Some of the difficulties inherent in determining which fish had active gonads were resolved by limiting the discussion to those fish collected from August to March.

Table XVII summarizes the results of examination of 135 whitefish collected during the August to March period. No specimens in age class I appeared to possess active gonads. However, two males in age class II appeared to be mature, inasmuch as their testes were enlarged and milky white. A little more than half of the fish of both sexes in age class III were immature. Gonads of most of the males in age class IV appeared active. Relatively fewer of the females possessed functional gonads. It is of interest to note that females appear to lag behind males in sexual development.

All of the fish collected in February and March were spent except one female collected February 16 which contained large eggs and apparently was a spawning straggler. The scales of 10 of the 13 fish collected in February and March revealed they were all of age class IV, V, or VI.

TABLE XVII

SEXUAL MATURITY (FISH WITH ACTIVE GONADS)

Age class	I	II	III			IV		V		VI	
	Im.	♂	Im.	♂	♀	♂	♀	♂	♀	♂	♀
Number of fish examined	12	2	10	26	17	20	20	13	9	1	5
Number sexually mature		2		14	10	19	16	13	9	1	5
Percent sexually mature		** 16		54	48	95	80	100	100	100	100
Number immature	12		10	12	7	1	4				
Percent immature	100		** 84	46	42	5	20				

Im. immature.
** combined data.

No spent fish were taken in the October and November collections, although two females appeared to have lost some of their eggs because of struggling in the net. It is therefore probable that whitefish in Flathead Lake spawn sometime in December or January.

Discussion - Fecundity.

Table XVIII summarizes the few data available concerning egg counts of whitefish taken in Flathead Lake. Volumetric determinations were made by members of the class in ichthyology at Montana State University and indicate a range of about 5,500 to 12,000 eggs per pound of fish. Egg counts obtained by Hart (1930) for whitefish of the Bay of Quinte, Lake Ontario, were somewhat lower: 4,000-6,500 per pound of live weight. However, Hart stripped the fish rather than removing the ovaries intact, as was done here.

Discussion - Conclusions Concerning the Population of *Coregonus* of Yellow and Polson Bays.

With reference to the previous discussion, the writer, on the basis of the data available, was able to find little evidence for localization of populations in Yellow and Polson Bays. This conclusion is based on the following observations:

1. The apparently temporary residence of the older age classes in Polson Bay.

TABLE XVIII

EGG COUNTS FROM COREGONUS

Fish number	Date collected	Age	Weight (grams)	Volumetric count	Eggs per pound of fish (live weight)
295-51	October 13, 1951	III	420	9,270	8,528
299-51	October 13, 1951	III	594	15,400	11,760
306-51	November 3, 1951	V	682	8,844	5,896
310-51	November 3, 1951	III	474	6,285	5,986

2. Similar age composition of the whitefish collected in Yellow Bay as against those collected in Polson Bay.

3. Similar maximum ages for whitefish collected in the two bays.

4. Similar weight-length relationships of whitefish collected in the two bays.

5. Similar coefficients of condition.

6. Similar sex ratios (exception was found in age class IV, but overall ratios were much alike).

FOOD-TAKING

Methods.

The presence of food in the stomachs of whitefish was noted on the same cards as those used to record length, weight and other pertinent data. The stomach contents of each fish were placed in individual glass vials and were preserved in 7 to 8% formalin. A few of the stomachs were preserved intact. These were slit open to allow free contact of contents with formalin. A strip of heavy note paper bearing a number corresponding to the fish number assigned the specimen was placed in each vial. Contents of stomachs taken from fish which were left in the nets an abnormally long time were not included in the analysis. As an example, the whitefish collected in Polson Bay on July 16, 1952 were taken in gill nets set for two nights and one day, whereas most nets were set only over one night. Length of time between setting and pulling gangs was roughly comparable in all parts of the lake (see appendix). There was some tendency for the nets set in Polson Bay to be pulled later in the morning than those nets set in Yellow Bay because of the time consumed in traveling the 10 miles to Polson Bay by motor launch. The high percentage of full stomachs and the state of preservation of the Polson Bay material indicated little bias because of the time element. Some of the immature insects in these stomachs were still alive at the time they were placed in formalin. Care was taken to avoid including intestinal contents as inclusion of intestinal material would probably tend to introduce error into the results in the form of emphasis on the hard shelled forms.

Identifications and counts were made by spreading the contents of each stomach vial in a finger bowl with a little water. Gravel and detritus were separated from the food items. Confirmation of identifications were made by staff members of the Montana State University departments of Zoology and Botany. In addition, several specialists in various fields of invertebrate taxonomy, whose help is gratefully acknowledged in the front of this manuscript, verified certain of the identifications. Specific identifications were impossible or impractical for a number of the groups.

Numbers of Chironomid larvae and pupae and of amphipods were determined by "head counts" in order to standardize the counting procedure and eliminate errors which might result from counting parts of macerated forms. Counts of the number of colonies were made for the two colonial algal forms most frequently found.

The total volume of the food items in each stomach was determined by displacement of the food items in water in a glass cylinder graduated to 0.2 cc. Estimates were made to the nearest 0.1 cc. Food in amounts below the latter value was recorded as a 'trace'. All food items were blotted on fine, pourous paper toweling to remove excess moisture before displacement in the graduate. The quantity of Crustacean microplankton was determined volumetrically in the same manner as that described for total food volume.

The discussion of the diet of Coregonus in Flathead Lake is based on the examination of 515 stomachs, 372 of which contained food varying in amount from a trace to 7.00 cc.

Results and Discussion.

Tables XIX through XXXV summarize the seasonal trends, both qualitative and quantitative, of the diet of Coregonus in Flathead Lake. The order of presentation allows the reader to begin with the winter and early spring collections and follow the dietary sequence chronologically through late autumn. The items in the tables are arranged in the order of their frequency of occurence. The number of stomachs which contained food for each of the periods summarized is indicated in the titles of the tables. It is this figure on which the average number or volume of each food item is based. Empty stomachs were not included in any of the computations. An indication of the number of stomachs which contained food to those which were completely empty will be found in another part of this discussion.

The analysis of stomachs of whitefish taken from Yellow Bay in February and March is summarized in Table XIX. Chironomid larvae were found most frequently in these stomachs. Water mites were second in both occurrence and average number. Amount of all other items were negligible except for the one stomach which contained Cladocera. Plant seeds are enumerated in the tables because it has not been established that seeds are not utilizable by whitefish once the seed coats are ruptured. The data in table XIX indicate that whitefish in Yellow Bay do at least some feeding during the winter months.

TABLE XIX

FOOD OF 6 *COREGONUS* COLLECTED IN YELLOW BAY, FEBRUARY 16 AND MARCH 22, 1952

Food Organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Chironomid larvae	4	134	50		
Hydrachnida	2	54	10		
Pisidium	2	2	—		
Cladocera	1			.2 cc	.03 cc
Cladophora	1			trace	trace
Other algae	1			trace	trace
Nematoda	1	1	—		
Seeds (higher plants)	1	1	—		
Ostracoda	1			trace	trace

Table XX indicates that in Yellow Bay in May, Chironomid larvae and water mites, the latter composed almost entirely of Hygrobates decaporus, were still the most frequently ingested food items of whitefish. However, water mites, though of frequent occurrence, usually were of negligible volume. Small mollusca, notably Valvata humeralis and Pisidium were also quite prevalent in the stomach contents. It is of interest to note the relatively large number of stomachs which contained chironomid pupae during this period. The presence of pupae along with the fact that one of the stomachs contained a large number of Chironomid adults reflects an emergence of those forms. A similar situation was noted at other times and places during the spring and early summer, indicating more than one emergence occurred. Cladophora was the alga most often present in the stomachs of the May collection in Yellow Bay. However, the volume of this form was negligible. The Nematodes enumerated in this and other cases belong to the genera Hydramermis and Cystidictola. They are apparently digested by whitefish, though their presence is not the result of active feeding but rather a chance matter inasmuch as these two forms are known to parasitize chironomids and trichopterans.

Table XXI indicates that whitefish in Polson Bay were also feeding upon chironomid larvae more frequently than any other dietary item during the spring of 1952. A

TABLE XX

FOOD OF 32 *COREGONUS* COLLECTED IN YELLOW BAY, MAY 4, 16, 17 AND 18, 1952

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Chironomid larvae	24	305	104		
Hydrachnida	24	109	10		
Chironomid pupae	13	16	2		
Valvata humeralis	10	7	1		
Pisidium	7	10	1		
Nematoda	6	9	1		
Cladophora	6			trace	trace
Other insects and parts	4	3	—		
Gyraulus	4	5	—		
Bryozoan tubes	4			trace	trace
Bryozoan statoblasts	4	5	—		
Amphipoda	3	3	—		
Seeds (higher plants)	3	3	—		
Copepoda	3			trace	trace
Ostracoda	2			trace	trace
Other algae	2			trace	trace
Chironomid adults	1	203	6		
Fish, small*	1	12	—		

*Too small to identify.

TABLE XXI

FOOD OF 14 *COREGONUS* COLLECTED IN FOLSOM BAY, APRIL 20, MAY 4, AND MAY 17, 1952

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Chironomid larvae	13	327	126		
Pisidium	13	66	23		
Amphipoda	12	39	12		
Seeds (higher plants)	11	34	8		
Valvata humeralis	10	71	13		
Hydrachnida	10	20	6		
Oculobdella sp.	9	8	2		
Gyraulas	8	105	11		
Valvata tricarinata	8	59	11		
Trichoptera	8	15	3		
*Aphanothece**	5	50	4		
Fossaria	5	2	—		
Anacharis	4			0.1 cc	trace
Nematoda	3	17	2		
Other algae	3			trace	trace
Other insects and parts	3	2	—		
Ephemerida	1	21	1		
Musculium	1	1	—		
Ostracoda	1			trace	trace
Bryozoan statoblasts	1	1	—		

*Number of colonies

comparison of tables XX and XXI reveals that chironomids were taken in approximately equal amounts in both Polson Bay and Yellow Bay during May. However, in most of the cases which follow, stomachs from Polson Bay showed far greater numbers of this form. Molluscs, primarily _Pisidium_, _Valvata humeralis_, _Valvata tricarinata_ and _Gyraulus_, were of frequent occurence. Further study of tables XX and XXI reveals that amphipods were a notable food item in the Polson Bay stomachs but were almost negligible in number and frequency in the Yellow Bay collections. Small leeches did not occur in stomachs of whitefish collected from any other part of the lake, probably because they exist in very low numbers outside of Polson Bay. Trichoptera, mostly Limnophilidae, are conspicuous at this time more by the volume than by their number. Trichoptera, along with the large olichochaete-like leech, _Erpobdella punctata_, are underemphasized in the frequency of occurence method of evaluation. It is not intended to imply that these forms play as important a part in the diet of whitefish as Chironomids or Molluscs, but volumetric analysis showed that one large Trichopteran may be volumetrically equal to 25 or 30 Chironomids and one large leech may provide more bulk than 100 Chironomids. At those times when they are present in appreciable numbers, leeches and Trichoptera undoubtedly make an important contribution to the diet of whitefish. Most of the other forms which were present in the stomachs of Coregonus are well represented by the 'frequency of occurence' approach.

In June, the dominance of Chironomids in stomachs collected in Polson Bay was especially marked (table XXII). Pisidium and Amphipods still ranked second and third respectively. However, Molluscs other than Pisidium are replaced by the leech, Oculobdella, and Aphanothece, a colonial blue-green alga.

Table XXIII shows that stomachs of whitefish collected in Yellow Bay during the last half of June, 1952, contained very few Chironomids. Valvata humeralis, various other Molluscs and water mites were more frequently the main components of the diet at that time. Some idea of the variation which may occur in collections taken at the same general place and in the same season, but in different years, may be obtained from a comparison of tables XXIII and XXIV. In 1951, during a similar period, Chironomid larvae predominated in the stomach contents of whitefish.

The erroneous picture that one or a few collections from one area and time may create may be seen in the composite of tables XXII to XXV. The composite picture emphasizes the importance of Chironomids and small Molluscs in both Yellow and Polson Bays. The same tables indicate that some items which may occur relatively frequently in the diet of whitefish one year may be practically absent the

TABLE XXII

FOOD OF 31 <u>COREGONUS</u> COLLECTED IN POLSON BAY, JUNE 1, AND 21, 1952

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Chironomid larvae	29	760	270		
Pisidium	29	54	14		
Amphipoda	27	96	17		
Oculobdella sp.	27	55	14		
*Aphanothece**	22	47	7		
Seeds (higher plants)	22	25	6		
Chironomid pupae**	13	25	4		
Valvata humeralis	13	42	3		
Valvata tricarinata	10	59	3		
Nematoda	9	20	1		
Trichoptera	7	3	—		
Gyraulus	6	14	1		
Hydrachnida	6	4	—		
Ostracoda	4			trace	trace
Erpobdella punctata	3	6	—		
Chara	3			trace	trace
Other insects and parts	2	1	—		
Musculium	1	1	—		
Bryozoan statoblasts	1	1	—		
Cladocera	1			trace	trace

*Number of colonies.
**All on June 21.

TABLE XXXIII

FOOD OF 14 COREGONUS COLLECTED IN YELLOW BAY, JUNE 16-26, 1952

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Valvata humeralis	8	62	12		
Hydrachnida	7	89	11		
Chironomid pupae	5	16	2		
Other insects and parts	4	2	—		
Valvata tricarinata	3	26	2		
Gyraulus	3	6	1		
Pisidium	3	3	—		
Chironomid larvae	3	1	—		
Fossaria	2	2	—		
Bryozoan statoblasts	2	3	1		
Bryozoan tubes	1			trace	trace
Amphipoda	1	1	—		
Cladophora	1			trace	trace
Other algae	1			trace	trace
Seeds (higher plants)	1	1	—		

TABLE XXIV

FOOD OF 9 <u>COREGONUS</u> COLLECTED IN YELLOW BAY, JUNE 19, 20, AND 21, 1951

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Chironomid larvae	8	83	19		
Nematoda	4	6	1		
Cladophora	4			trace	trace
Pisidium	3	8	1		
Hydrachnida	3	8	1		
Other insects and parts	3	5	1		
Valvata humeralis	2	32	4		
Seeds (higher plants)	2	3	—		
Trichoptera	2	1	—		
Bryozoan tubes	2			0.1 cc	trace
Gyraulus	1	67	7		
Valvata tricarinata	1	4	—		
Other algae	1			trace	trace
Amphipoda	1	1	—		
Bryozoan statoblasts	1	1	—		

TABLE XXV

FOOD OF 16 *COREGONUS* COLLECTED IN POLSON BAY, JUNE 23, 1951

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs
Hydrachnida	15	463	54		
Chironomid larvae	15	266	48		
Pisidium	12	19	4		
Valvata humeralis	11	197	16		
Amphipoda	11	54	7		
Valvata tricarinata	9	118	15		
Ostracoda	7			trace	trace
Chara	7			trace	trace
Seeds (higher plants)	6	54	4		
Gyraulus	5	124	8		
Trichoptera	5	3	1		
Other insects and parts	5	3	—		
Nematoda	4	3	1		
Oculobdella sp.	3	12	1		
Chironomid pupae	3	2	—		
Fossaria	3	1	—		
Bryozoan statoblasts	1	1	—		
*Aphanothece**	1	1	—		
Helisoma anceps	1	1	—		
Erpobdella punctata	1	1	—		

*Number of colonies.

next. This pattern probably reflects the relative abundance of the various organisms from year to year and suggests that up to July of each year whitefish in Flathead Lake feed directly on the bottom of the lake and eat whatever bottom organisms are available.

By comparing table XXVI and XXVII it may be seen that the main constituents of the stomach contents of the July 7 collection from Polson Bay differed little from those present in collections from the same place in June. Chironomid larvae continued to predominate in the July 7 collection (table XXVI). Aphanothece, Pisidium, plant seeds and the small leech, Oculobdella sp. were of frequent occurence in July just as they were in June. However, a decline in both the frequency of occurence and the average number of Amphipoda took place.

A dramatic mid-summer change occurs in the diet of whitefish in Flathead Lake. July and August collections of whitefish from several parts of the lake reveal that micro-Crustacea (here Cladocera and Copepoda) suddenly become the major dietary constituent. This 'plankton-shift' occured in Yellow Bay during the first two weeks of July in 1952, (table XXVII). The pattern was similar in 1951 for Yellow Bay (table XXVIII). In 1952 small collections of whitefish from other parts of Flathead Lake indicated that this shift in diet occurs over the entire lake.

TABLE XXVI

FOOD OF 42 *COREGONUS* COLLECTED IN POLSON BAY, JULY 7, 1952

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Chironomid larvae	41	810	343		
*Aphanothece**	40	66	12		
Pisidium	39	29	10		
Seeds (higher plants)	34	17	4		
Oculobdella sp.	30	42	6		
Trichoptera	24	9	2		
Amphipoda	17	4	1		
Hydrachnida	11	57	4		
Erpobdella punctata	10	3	—		
Valvata humeralis	8	5	—		
Chara				0.7 cc	trace
Valvata tricarinata	3	39	2		
Other insects and parts	3	1	—		
Chironomid pupae	2	5	—		
Gyraulus	1	1	—		
Fossaria	1	1	—		
Bryozoan statoblasts	1	1	—		
Other algae	1			trace	trace
Anacharis	1			trace	trace
Ostracoda	1	1	—		

*Number of colonies.

TABLE XXVII

FOOD OF 29 COREGONUS COLLECTED IN YELLOW BAY, JULY 2, 10, 20, AND 27, 1952

Food Organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Cladocera	17			1.3 cc	0.15 cc
Copepoda	11			0.1 cc	trace
Insects and parts*	10	28	1		
Chironomid larvae	6	7	1		
Chironomid adults	3	110	4		
Valvata humeralis	3	6	—		
Fossaria	2	5	—		
Chironomid pupae	2	2	—		
Leptodora	2			trace	trace
Seeds (higher plants)	1	5	—		
Hydrachnida	1	4	—		
Trichoptera	1	1	—		
Bryozoan tubes	1			trace	trace
Nematoda	1	1	—		
Unidentified algae	1			trace	trace

*Mostly Hymenoptera.

TABLE XXVIII

FOOD OF 18 COREGONUS COLLECTED IN YELLOW BAY, JULY 20, AND 21, 1951

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Insects and parts*	10	4	1		
Cladocera	7			.2cc	.03 cc
Valvata humeralis	5	15	2		
Chironomid larvae	4	5	1		
Hydracnnida	3	6	1		
Chironomid pupae	3	2	—		
Bryozoan tubes	2			3.0 cc	.2 cc
Cladophora	2			trace	trace
Pisidium	1	10	1		
Gyraulus	1	3	—		
Trichoptera	1	2	—		
Valvata tricarinata	1	1	—		
Fossaria	1	1	—		

TABLE XXIX

FOOD OF 10 *COREGONUS* COLLECTED IN POLSON BAY, JULY 30, 1952

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Chironomid larvae	9	295	92		
Cladocera	6			0.7 cc	0.2 cc
Seeds (higher plants)	6	5	2		
*Aphanothece**	6	14	4		
Hydrachnida	6	18	3		
Pisidium	5	10	3		
Copepoda	4			0.1 cc	trace
Chironomid pupae	4	1	—		
Trichoptera	3	3	—		
Oculobdella sp.	2	8	1		
Amphipoda	2	2	—		
Other insects and parts	2	1	—		
Valvata humeralis	1	1	—		
Gyraulus	1	1	—		
Musculium	1	1	—		
Bryozoan statoblasts	1	1	—		

*Number of Colonies.

Stomachs taken from whitefish collected in Polson Bay on July 30, 1952, Table XXIX, revealed that Cladocera and Copepoda had become a very conspicuous food item, whereas on July 7, 1952, (table XXVI) no Cladocera or Copepoda were found in any of the 42 stomachs which contained food.

Whether this 'shift' occurs as a result of the normal seasonal decline of bottom fauna in company with a plankton 'pulse' is not known. A comparative seasonal investigation of the quantitative and qualitative benthos and plankton of Flathead Lake is desirable.

Tables XXX to XXXV indicate that micro-Crustacea continue to predominate in all of the collections through November, even where other forms such as Chironomids, occur in as many stomachs. Micro-Crustacea almost invariably contributed the greatest proportion of the food present. It is of interest to note the presence of Leptodora in the stomachs of whitefish collected in the fall of both 1951 and 1952. This cladoceran, seldom taken in plankton nets in Flathead Lake, was reported previously by Brunson and Newman (1951) in the summer food of Coregonus and by Brunson, Pennington, and Bjorklund (1952) in the fall food of the cutthroat trout, Salmo clarkii. On November 22, 1952, Leptodora was found in 14 of 17 whitefish stomachs which contained food (table XXXV). Of further interest in the November 22, 1952 collection was the presence of eggs of the kokanee, Oncorhynchus nerka in the stomachs of three of the whitefish collected on that date. One of these

TABLE XXX

FOOD OF 21 <u>COREGONUS</u> COLLECTED IN YELLOW BAY, AUGUST 16, 1952

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Copepoda	19			3.8 cc	.62 cc
Chironomid larvae	15	97	9		
Cladocera	11			0.1 cc	.07 cc
Seeds (higher plants)	11	7	--		
Pisidium	5	1	--		
Other insects and parts	5	1	--		
Bryozoan tubes	3			2.7 cc	0.1 cc
Hydrachnida	3	2	--		
Nematoda	3	3	--		
Gyraulus	2	7	--		
Fossaria	1	2	--		
Bryozoan statoblasts	1	2	--		
Valvata humeralis	1	1	--		

TABLE XXXI

FOOD OF 10 COREGONUS COLLECTED IN YELLOW BAY, SEPTEMBER 19, 1952

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Leptodora	7			1.4 cc	.33 cc
Other Cladocera	4			.6 cc	.10 cc
Chironomid larvae	4	740	221		
Chironomid pupae	2	2	--		
Pisidium	2	2	--		
Nematoda	1	15	1		
Seeds (higher plants)	1	3	--		
Other insects and parts	1	1	--		
Hydrachnida	1				
Aphanocapsa sp.*	1	2	--		
Ostracoda	1	1	--		

*Colonies.

TABLE XXXII

FOOD OF 11 COREGONUS COLLECTED IN YELLOW BAY, OCTOBER 1, 1952

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Chironomid larvae	6	142	17		
Hydrachnida	6	62	12		
Other insects and parts**	5	30	3		
Leptodora	4			.70 cc	.13 cc
Seeds (higher plants)	3	2	—		
Other Cladocera	2			trace	trace
Pisidium	2	2	—		
Valvata humeralis	2	1	—		
*Aphanocapsa**	1	31	3		
Bryozoan statoblasts	1	7	1		
Copepoda	1			trace	trace
Trichoptera	1	1	—		
Gyraulus	1	1	—		

*Colonies.

**Mostly adult Diptera.

TABLE XXXIII

FOOD OF 12 COREGONUS COLLECTED NEAR BULL ISLAND, OCTOBER 2, 1952

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Cladocera	9			1.2 cc	0.4 cc
Chironomid pupae	5	4	1		
Leptodora	3			0.1 cc	trace
Hydrachnida	3	365	31		
Chironomid larvae	1	1	—		
Ephemerida	1	1	—		
Amphipoda	1	1	—		

TABLE XXXIV

FOOD OF 13 COREGONUS COLLECTED IN YELLOW BAY OCTOBER 13, 1951

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Cladocera	9			.6 cc	.13 cc
Leptodora	4			.7 cc	.08 cc
Hydrachnida	4	240	25		
Insects and parts	3	2	—		
Bryozoan statoblasts	3	2	—		
Cladophora	2			trace	trace
Valvata humeralis	1	3	—		
Pisidium	1	1	—		
Aphanocapsa*	1	1			
Bryozoan tubes	1			trace	trace
Chara	1			trace	trace

*Colonies.

TABLE XXXV

FOOD OF 17 CORECONUS COLLECTED IN YELLOW BAY, NOVEMBER 22, 1952

Food organism	Number of stomachs found in	Greatest number in any stomach	Average number (all stomachs)	Greatest volume in any stomach	Average volume (all stomachs)
Chironomid larvae	15	9	3		
Leptodora	14			0.6 cc	.10 cc
Other Cladocera	11			0.8 cc	.12 cc
Hydrachnida	8	4	1		
Salmon eggs*	3			7.0 cc	2.4 cc
Bryozoan tubes	2			.2 cc	trace
Pisidium	1	6	—		
Seeds (higher plants)	1	2	—		
*Aphanocapsa***	1	1	—		
Other algae	1			trace	trace

*Oncorhynchus nerka.

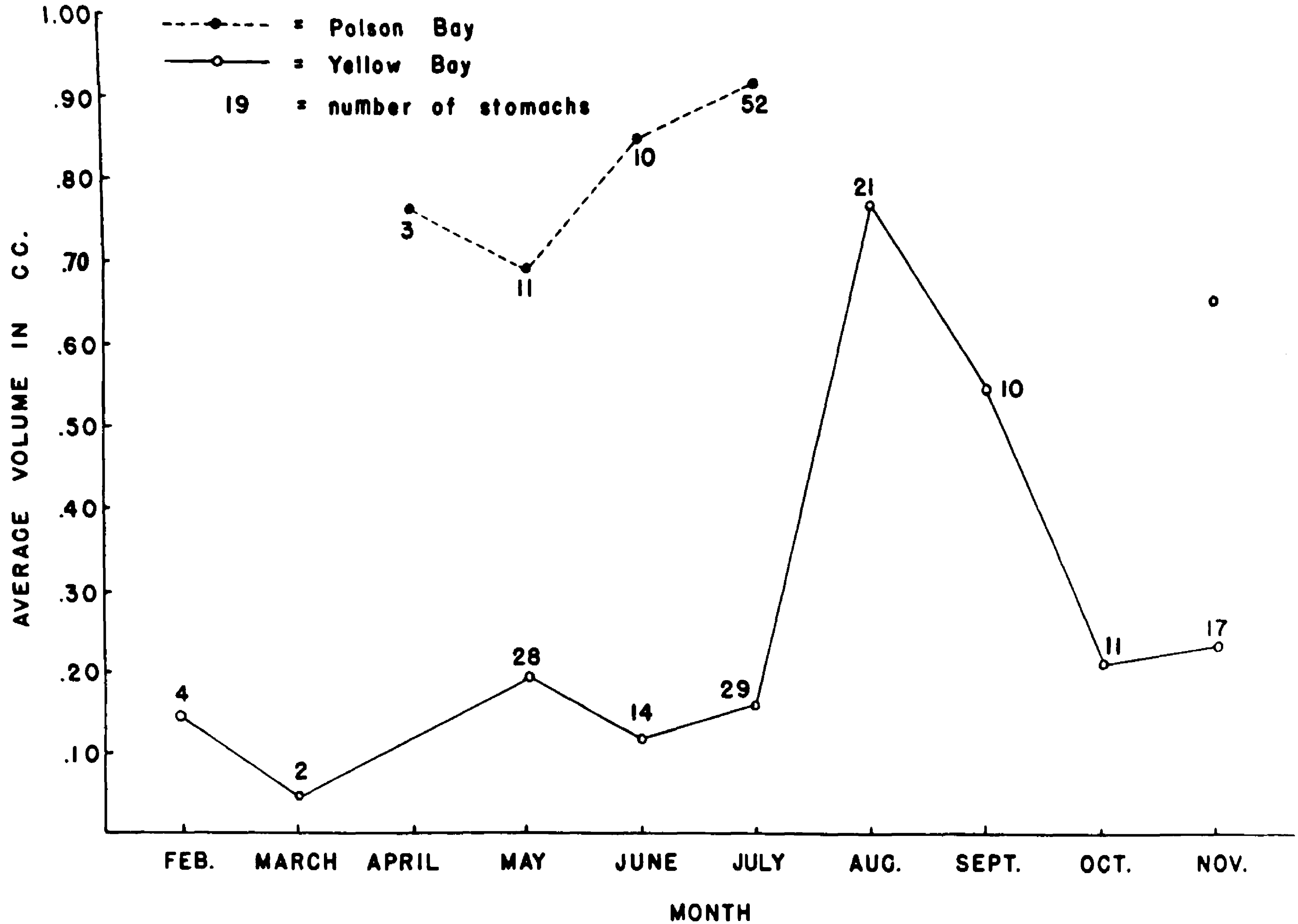
**Colonies.

stomachs contained 7.0 cc. of eggs - a volume of food much greater than found in any other stomach during the entire collecting period from May 1951 to November 1952.

In order that certain relations which are difficult to draw from the tabular material may be more easily perceived, figures 9 and 10 have been prepared. Only those stomachs which contained food were used in these tables.

Figure 9 indicates the relatively greater average total volume of food measured in cc. present in the stomachs of whitefish collected in Polson Bay during the spring and summer of 1952, as against those collected in Yellow Bay during the same period. Average volumes of stomach contents in Polson Bay varied from a low of .69 cc. for 11 stomachs collected in May to a high of .90 cc. for the average of 52 stomachs collected in July. Stomachs of whitefish from Yellow Bay averaged between .11 and .20 cc. of food during the same period. Figure 9 also shows that the total volume of food in the stomachs of whitefish in Yellow Bay increases sharply in August coincident with the 'plankton-shift.' The small circle above the November collection indicates what the average food volume for that date would be if the stomach which contained 7.0 cc. of salmon eggs was considered in the preparation of the graph. The value for average food volume in November is based on the contents of the other 16 stomachs in the collection.

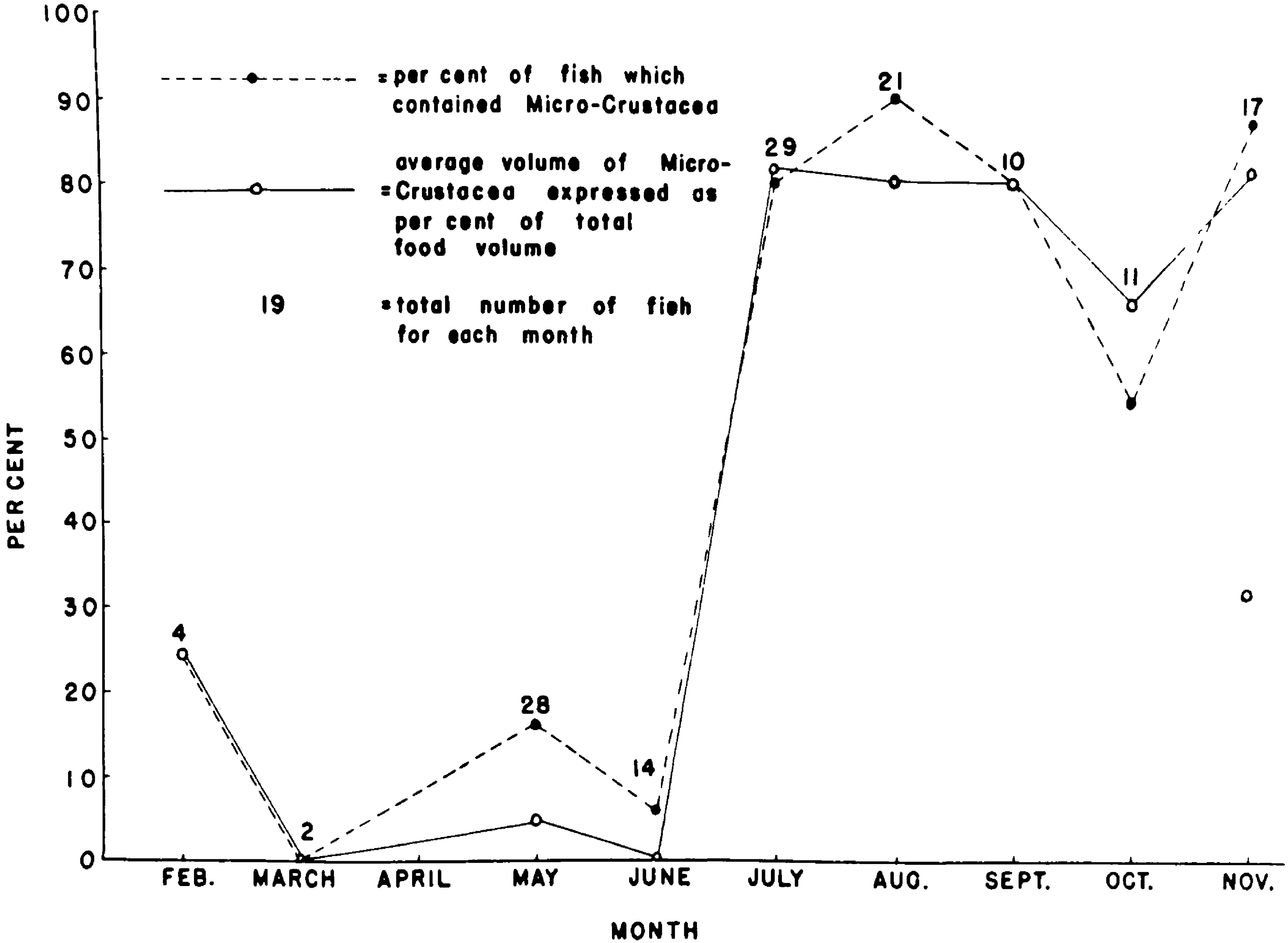
Figure 9. Average monthly total food volume for whitefish collected from Yellow and Polson Bays 1952. Numbers above the line graphs indicate the number of stomachs which contained food on each date.


= Polson Bay
= Yellow Bay
19 = number of stomachs
AVERAGE VOLUME IN CC.
1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
3
11
10
52
4
2
28
14
29
21
10
11
17
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
MONTH

Along with the data on stomach content volumes indicated in figure 9 it may be significant to note the number of empty stomachs in whitefish collected in Yellow Bay as against whitefish collected in Polson Bay. During the first 6 months of 1952, 47 of 130 specimens in Yellow Bay contained empty stomachs while only 4 empty stomachs were found in the 100 fish collected in Polson Bay during the same period. These figures emphasize the importance of Polson Bay as a feeding reservoir during the early part of the year. The state of flux in the population in Polson Bay as discussed in the section on depth distribution along with the shift to a diet of plankton in July and August seems to indicate that Polson Bay serves as a food reservoir for whitefish for only a part of the year. Nevertheless Polson Bay plays an important role in the food relations of whitefish in Flathead Lake.

Figure 10 presents in graphic form the seasonal trend in micro-Crustacea in the stomachs of whitefish taken in Yellow Bay during 1952. There is a very close relationship between the graphs of the percentage of whitefish which contained micro-Crustacea and the average volume of micro-Crustacea expressed as a percentage of the total food volume. As in figure 9, the stomach which contained 7.0 cc. of salmon eggs was not used in calculating the November values. However, the dot above November in the open part

Figure 10. Percentages of fish which contained micro-Crustacea and average volumes of micro-Crustacea expressed as percentages of the total food volume from whitefish collected in Yellow Bay, 1952.



= per cent of fish which contained Micro-Crustacea
average volume of Micro-Crustacea expressed as per cent of total food volume
19 = total number of fish for each month
PER CENT
MONTH
FEB.
MARCH
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
0
10
20
30
40
50
60
70
80
90
100
4
2
28
14
29
21
10
11
17

of the plate is the result of including this exceptional case in the calculations. The data show clearly that micro-Crustacea was the chief dietary constituent during the last half of 1952. Collections from 1951 indicate a similar situation existed for that year.

The food study thus strongly suggests that Chironomid larvae and micro-Crustacea are the two most important groups of organisms in terms of frequency of occurence and bulk in the diet of whitefish in Flathead Lake. In spite of the fact that the food of Coregonus varies somewhat with the year, season and location in the lake, Chironomidae usually predominate in collections made during the first 6 months of the year and micro-Crustacea usually predominate thereafter. Small Molluscs, notably Pisidium are also a conspicuous dietary constituent of whitefish. Amphipods, leeches, and Trichoptera contribute to the diet of whitefish in Polson Bay in spring and early summer. Most of the other food items are of little volumetric significance. This does not imply that they are of entirely negligible significance. However, such items as algae and surface insects seldom dominated in any of the collections.

SUMMARY

1. This investigation treats the natural history of the lake whitefish, Coregonus clupeaformis (Mitchill), as the species exists in Flathead Lake. Age, condition, food-taking, depth distribution and movements are emphasized. In addition, such special topics as sex ratios, sexual maturity, and time of annulus formation, are considered.

2. The lake whitefish of Flathead Lake is presumed not to be an indigenous form. Its history in Flathead Lake has been relatively brief.

3. It is probable that the lake whitefish population of Flathead Lake is little exploited.

4. Two bays of dissimilar physical and biological characteristics were chosen as sites of intensive collections. Supplementary collections were made in other parts of the lake.

5. The experimental gill nets used in this investigation did not take random samples of the smallest size whitefish.

6. The largest meshes, 3 and 4 inches (square measure), used in this investigation caught no whitefish.

7. Only one lake whitefish was taken in the 2½ inch mesh.

8. The collecting gear did not appear to be selective

against the largest whitefish.

9. No conspicuous gaps in the data appeared when mesh size was checked against standard length.

10. Fyke nets proved useless as whitefish traps during the summer of 1952.

11. Whitefish in Yellow Bay appeared to concentrate at depths of 15 to 30 meters from July to November.

12. Whitefish above age class I appeared to emigrate from Polson Bay in late July and August. The movement was accompanied by a rise in water temperature.

13. Ages of 507 whitefish were determined by the scale method.

14. In order to avoid grave errors in determination of age, the time of annulus formation was derived from a comparative study of the scales of specimens collected in spring and early summer. New annuli were laid down between mid June and mid July in both 1951 and 1952.

15. The paucity of large, old whitefish in the Flathead Lake collections does not appear to be the result of gear selection but may result from heavy mortality among the older age classes, or less likely, from the movement out of the lake by the older fish. The number and place of sets probably would have revealed the presence of any great number of older individuals. The oldest individual taken belonged to age class VIII and weighed 803 grams.

The largest individuals taken were both males which weighed 1034 and 1084 grams and which belonged to age class VII and VI respectively. No whitefish in age class O were taken. The smallest specimen belonged to age class I, weighed 36 grams and measured 14.1 cm. standard length.

16. Age-length frequencies revealed that whitefish in age classes III, IV and V collected in Yellow Bay differed very little in standard length for any one class for the years 1951 and 1952. Polson Bay specimens in age classes III and IV were somewhat larger. It was thought that the more favorable environment of Polson Bay during the first part of the year may have been the cause of the observed difference.

17. Age class III dominated the 1951 collections, and age class IV in the 1952 collections. The success of the 1947 year class over those of 1946 and 1948 was reflected in this shift.

18. The weight-length regression lines were not significantly different for samples taken from Polson and Yellow Bays during the summer of 1952. The calculated slope of this line is 2.84 and the log value of the constant 'a' is -1.61612.

19. The value of the coefficient of condition "K", as an indicator of physiological vigor, is doubtful, inasmuch as a large number of factors may influence this

index. For whitefish in Flathead Lake "K" did not vary with the year, sex or location within the lake, but did vary with the season. The mean value was lowest in the spring, especially in spent fish.

20. Overall sex ratios in the summer and fall collections approach 50:50. The spring collections, for some unknown reason, contained only about 40% males.

21. Males appear to mature earlier than females. Gross examination of the gonads of whitefish taken in the fall and spring revealed that some males of age class II had active testes. Most of the males in age class IV appeared mature. A number of females in this age class possessed inactive ovaries. All fish in age class V and above possessed active gonads. Spawning probably occurs in January or February.

22. The few data from egg counts revealed that Coregonus in Flathead Lake produces about 5,500 to 12,000 eggs per pound of live weight.

23. Inasmuch as whitefish from Yellow and Polson Bays exhibited similar age compositions, maximum ages, length-weight relationships, coefficients of condition and sex ratios, it is impossible to discern "local" populations within the two bays. In addition, the mid-summer exodus from Polson Bay indicated that the population in that bay is in a state of flux.

24. The most important food items for whitefish were Chironomid larvae during the first 6 months of the year, and micro-Crustacea thereafter. Small molluscs, notably *Pisidium*, are also important. Other items are of local or seasonal significance.

25. The high percentage of full stomachs and higher average volumes of total food contents in the Polson Bay specimens during the spring and early summer revealed the importance of that bay as a feeding reservoir.

26. Micro-Crustacea predominated in both percent volume of total food contents and in frequency of occurrence in the stomachs of whitefish taken from July through November.

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APPENDIX

Summary of Net Sets

GILL NET SETTINGS YELLOW BAY - 1951

NET SET NUMBER	LOCATION	BOTTOM CHARACTER	DATE	NET LETTER	TOTAL FEET NET	NUMBER OF WHITEFISH	LENGTH OF SET (HOURS)	DEPTH RANGE (METERS)
1-51	Biological Station Dock	Mud-Detritus	May 19	*	150	1	16	5.0-
2-51	Point, South	Rocky Ledge	May 19	*	150	1	16¼	2.5-
5-51	Point, South	Rocky Ledge	May 20	*	300	6	17	2.5-
6-51	Inner Bay	Mud-Chara	May 20	*	300	8	20	3.5-20.0
9-51	Point, West	Rock-Gravel	May 28	*	150		--	--
10-51	Biological Station Dock	Gravel-Mud	June 19	*	450	4	12½	10.0-25.0
11-51	Point, East	Gravel-Mud	June 20	*	450	4	9½	2.0-32.0
12-51	Point, East	Gravel-Mud	June 21	*	450	4	11	6.0-30.0
17-51	Point, East	Gravel-Mud	June 28	*	450	3	12	2.0-32.0
18-51	Point, East-Profundal	Mud	June 30	A,B,C, D,E	750		8 3/4	17.0-32.0
19-51	Inner Bay	Mud-Chara	July 5	D,E	300	2	10 3/4	15.0-16.0
20-51	Point, East-	Gravel-Mud	July 5	A,B,C	450	1	11	2.0-32.0
22-51	Point, East-Profundal	Mud	July 7	A,B,C	450	2	12	20.0-32.0
23-51	Inner Bay	Gravel-Mud	July 7	D,E	300		12	10.0-16.0
24-51	Inner Bay	Mud-Chara	July 12	A,B	300	4	9 3/4	15.0-16.0

*First 17 sets 1951 without net letter designation.

GILL NET SETTINGS YELLOW BAY - 1951 (CONTINUED)

NET SET NUMBER	LOCATION	BOTTOM CHARACTER	DATE	NET LETTER	TOTAL FEET NET	NUMBER OF WHITEFISH	LENGTH OF SET (HOURS)	DEPTH RANGE (METERS)
25-51	Point, East-Profundal	Mud	July 12	D,C	300		10	20.0-32.0
26-51	Point, East	Gravel	July 12	E	150	4	10½	1.5-10.0
27-51	Point, South	Rocky ledge	July 13	B	150		12	2.0-4.0
28-51	Point, East	Rock, Gravel-Mud	July 14	A,B,F	450	1	8½	2.0-32.0
29-51	Point, South	Rocky ledge	July 14	C,D,E	450	9	9½	2.0-12.0
35-51	Point, East	Rock, Gravel-Mud	July 20	A,B,D	450	3	11	2.0-32.0
36-51	Inner Bay	Gravel-Mud	July 20	C,E,F	450	7	10 3/4	6.0-15.0
37-51	Point, East	Gravel	July 20	****	300	5	—	1.5-16.0
38-51	Point, Toward Inner Bay	Gravel-Mud	July 21	300x12 150x12	450	17	*22½	5.0-25.0
39-51	Point, South	Rocky ledge	July 21	A,B,D	450	1	20½	3.0-25.0
40-51	Inner Bay	Mud-Detritus	July 21	C,E,F	450	26	*18½	3.0-15.0
41-51	Biological Station Dock	Mud-Detritus	July 21	****	300		15½	4.0-8.0
42-51	Point, South	Rocky ledge	July 26	E	150		**10	2.5-6.0
43-51	Inner Bay-State Park	Gravel	July 27	A,E,D	450	9	*23	6.0-20.0
44-51	Point, South	Rocky ledge	July 27	C	150		11½	2.5-6.0
46-51	Inner Bay	Gravel-Mud	July 29	A,C	300	1	10½	3.0-16.0

****Net borrowed from Montana Fish and Game Department.

*Day and night set.

**Day set.

GILL NET SETTINGS YELLOW BAY - 1951 (CONCLUDED)

NET SET NUMBER	LOCATION	BOTTOM CHARACTER	DATE	NET LETTER	TOTAL FEET NET	NUMBER OF WHITEFISH	LENGTH OF SET (HOURS)	DEPTH RANGE (METERS)
48-51	Point, South	Rocky Ledge	Aug. 2	C,E	300	1	12	2.5-8.0
49-51	Point, East - Profundal	Mud	Aug. 2	B,D	300		12	28.0-32.0
50-51	Inner Bay - Below State Park	Gravel - some mud	Aug. 4	B,D	300	6	13 3/4	5.0-15.0
51-51	Point, South	Rocky ledge	Aug. 4	A,C	300		12	2.0-5.0
52-51	Point, South	Rocky ledge	Aug. 5	B	150		11 3/4	2.0-5.0
53-51	Point, South	Rocky ledge	Aug. 10	*—	150		18	— —
54-51	North-South Profundal	Mud	Aug. 12	A,B,C	450	5	12½	20.0-25.0
55-51	Point, South	Rocky ledge	Oct. 13	A,C,D,E	600	14	14	2.0-19.0
56-51	Point, West	Rock-gravel	Oct. 13	B,F	300	5	—	2.0-19.0
57-51	Point, West	Rock-gravel	Nov. 3	A,C	300	2	14½	2.0 —
58-51	Point, South	Rocky ledge	Nov. 3	B,D,E	450	3	16	2.0 —
59-51	Point, South	Rocky ledge	Nov. 24	A,D	300	1	**16	— —
60-51	Point, West	Rock-gravel	Nov. 24	C	150	2	**16	2.5 —
61-51	Inner Bay	Mud	Nov. 24	B,E	300	2	**16	8.0-16.0
62-51	Point, South	Rocky ledge	Dec. 9	B,D	300	1	15½	2.0 —
Totals					15,600	165		

*Letter not recorded (one 150 x 6 net).
**Approximate.

GILL NET SETTINGS OUTSIDE YELLOW BAY 1951

Net set number	Location	Bottom Character	Date	Net letter	Total Feet Net	Number of Whitefish	Length of set (Hours)	Depth Range (Meters)
3-51	Open Lake West of Yellow Bay	Rock-Gravel	May 19	*	150	2	17	4.0-
4-51	Open Lake West of Yellow Bay	Rock-Gravel	May 19	*	150		19	— —
8-51	Narrows Cliffs	—	May 26	*	150	2	17½	5.0-13.0
13-51	Polson Bay, West Side	Gravel-Mud	June 23	*	150	6	—	2.5-6.0
14-51	Polson Bay, West Side	Mud-Chara	June 23	*	150	4	—	6.0-6.0
15-51	Polson Bay, Middle	Mud	June 23	*	150	8	—	6.0-6.0
16-51	Rocks, South of Bull Isle	Rocky	June 23	*	150		—	— —
21-51	Melita Island	Rock-Gravel	July 6	A,B,C	450	9	12½	2.0-14.0
30-51	Open Lake West of Yellow Bay	Rock-Gravel	July 15	300x12 150x12	450	10	11 3/4	7.5-20.5
31-51	Open Lake West of Yellow Bay	Rock-Gravel	July 15	—	150		12½	2.0
32-51	Narrows Cliffs	—	July 19	E,F	300			3.0-13.0
33-51	East Side Finley Point	—	July 19	C,D	300	2	—	2.5-
34-51	Skidoo Bay	—	July 19	A,B	300	4	—	9.5-30.5
45-51	Open Lake West of Yellow Bay	Rock-Gravel	July 27	A	150		12½	2.0-
47-51	Open Lake West of Yellow Bay	Rock-Gravel	July 29	A	150		10 3/4	2.0-
Totals					3,300	47		

*No net designation for first 17 sets 1951.

GILL NET SETTINGS YELLOW BAY 1952

Net set number	Location	Bottom Character	Date	Net Letter	Total Feet Net	Number of Whitefish	Length of set (Hours)	Depth Range (Meters)
1-52	Point, West	Rock-Gravel	Feb. 16	B,D	300	9	18¼	2.0-
2-52	Point, South	Rocky Ledge	Feb. 17	A,C	300	1	19	2.0-
3-52	Point, South	Rocky Ledge	March 21	B,D,C	450	2	14	2.5
4-52	Inner Bay	Mud	March 21	A,C	300	1	14	16.0-16.0
5-52	Point, West	Rocky-Gravel	March 21	F	150		14	2.0-3.0
7-52	Inner Bay	Mud-Chara	April 20	F	150		17 3/4	2.5-15.5
8-52	Point, South	Rocky Ledge	April 20	B,E	300		16 3/4	2.0-12.0
9-52	Inner Bay	Gravel-Mud	April 20	D	150		17	3.5-10.0
12-52	Point, South	Rocky Ledge	May 3	C,E	300		*5	4.0-18.0
13-52	Inner Bay	Mud	May 4	F	150		15½	6.0-18.0
14-52	Inner Bay	Gravel-Mud	May 4	A	150		15½	5.5-18.0
15-52	Point, West	Rock-Gravel	May 4	300x12	300	2	14½	4.0-19.5
16-52	Point, South	Rocky Ledge	May 4	C,E	300	3	13½	3.0-20.5
17-52	Point, South	Rocky Ledge	May 16	300x12	300		13	3.5-19.0
18-52	Point, West	Rock-Gravel	May 16	D,F	300	9	12½	6.0-21.0

*Short Daylight set.

GILL NET SETTINGS YELLOW BAY 1952 (CONTINUED)

Net set number	Location	Bottom Character	Date	Net Letter	Total Feet Net	Number of Whitefish	Length of set (Hours)	Depth Range (Meters)
19-52	Point, East	Mud	May 16	A,C	300	3	11 3/4	2.0-22.5
20-52	Inner Bay, East Shore	Gravel	May 16	B,D	300	2	11 1/2	2.5-19.0
21-52	Point, West	Rock-Gravel	May 17	300x12	300	7	15 1/2	6.5-22.0
24-52	Inner Bay	Gravel-Mud	May 18	A,C	300	1	10 1/2	3.5-14.5
26-52	South Shore, Rock-slide	Rock-Gravel	May 18	A,C	300	6	15	2.0-17.0
27-52	Inner Bay	Mud	May 18	300x12	300	4	11 3/4	3.0-17.0
28-52	Inner Bay, near Point	Rocky	May 18	E,F	300		14	* *
29-52	Point, West	Gravel	May 18	B,D	300	8	12 1/2	5.5-15.0
32-52	Point, West	Gravel	June 1	B	150	2	9 3/4	5.5-10.5
33-52	Point, South	Rocky ledge	June 16	A,D	300	3	10 3/4	3.0-11.5
34-52	Inner Bay	Rock-Gravel	June 16	B	150		10 1/4	2.0-14.0
35-52	East Shore	Rock-Gravel	June 17	C,E	300	6	13	2.5-16.5
36-52	Point, West	Rocky	June 20	300x12 150x12	450	7	12	2.5-23.0
41-52	Open Bay, Profundal	Gravel-Mud	June 26	A,B,C,D,E	750	5	14 1/2	5.5-49.5
44-52	*Inner Bay, Profundal	Mud	June 30	300x12 150x12	450	2	13	20.0-27.0

*North-South.

**Set shallow parallel to shore.

GILL NET SETTINGS YELLOW BAY 1952 (CONCLUDED)

Net set number	Location	Bottom Character	Date	Net Letter	Total Feet Net	Number of Whitefish	Length of set (Hours)	Depth Range (Meters)
45-52	Point, South	Rocky Ledge	July 2	300x12 150x12	450	9	9½	5.0-25.0
51-52	Point, South	Rocky Ledge	July 10	A,C,D	450	4	12	5.0-26.0
55-52	Point, South	Rocky Ledge	July 20	A,C	300	21	13½	4.5-20.0
60-52	Inner Bay	Gravel-Mud	July 27	B,E	300	15	13½	6.0-20.0
62-52	Point, South	Rocky Ledge	Aug. 2	A,C	300	1	*12 3/4	10.0-22.5
66-52	Open Bay, Profundal	Mud	Aug. 9	A,C	300		*11½	27.5-34.0
72-52	Inner Bay	Gravel-Mud	Aug. 16	A,C	300	8	13½	4.0-22.0
73-52	Point, South	Rocky Ledge	Aug. 16	B,D,E	450	16	13	7.5-24.5
74-52	Inner Bay	Gravel-Mud	Sept.19	300x12	300		12	* *
75-52	Point, South	Rocky Ledge	Sept.19	A,B,C,D,E	750	12	12	3.0-29.0
76-52	Point, South	Rocky Ledge	Oct. 1	150x12	150		12½	4.0-6.0
77-52	South Shore Rock Slide	Rock-Gravel-Mud	Oct. 1	B,D,E	450	8	14	9.0-45.0
78-52	Point, West	Rock-Gravel	Oct. 1	A,C	300	7	14 3/4	9.0-21.5
80-52	Point, South	Rocky Ledge	Nov. 22	A,B,C,D,E	750	30	16½	2.0-34.5
81-52	Point, West	Rock-Gravel	Nov. 22	150x12	150	5	15½	18.5 —
Totals					14,550	219		

*Daylight Sets.
**Floating Set in shallow water.

GILL NET SETTINGS POLSON BAY 1952

NET SET NUMBER	LOCATION	BOTTOM CHARACTER	DATE	NET LETTER	TOTAL FEET NET	NUMBER OF WHITEFISH	LENGTH OF SET (HOURS)	DEPTH RANGE (METERS)
6-52	East Side	Mud-Chara	April 20	A,C	300	3	15¼	1.5-2.5
10-52	East Side	Mud-Chara	May 4	D	150	2	16¼	2.0-2.5
11-52	East Side	Mud-Chara	May 4	B	150	7	15½	3.0-3.5
22-52	Northeast	Mud	May 17	B,D	300	3	13¼	3.0-3.0
23-52	Northeast	Mud-Sand	May 17	E,F	300		12¼	2.5-3.0
30-52	West Side	Mud	June 1	A,D	300	5	17½	5.5-5.5
31-52	West Side	Mud	June 1	B,C	300	5	16 3/4	5.5-5.5
37-52	East Side	Mud-Chara	June 21	300x12	300	14	16 3/4	5.5-5.5
38-52	East Side	Mud-Chara	June 21	150x12	150	8	16½	5.5-5.5
42-42	Flathead River**	Rocky	June 28	B,C,E	450	3	11 3/4	3.5-3.5
43-52	Flathead River***	Rocky	June 28	A,D	300	3	10 3/4	3.0-4.0
49-52	East Side	Mud-Chara	July 7	150x12	150	13	18¼	6.0-6.0
50-52	East Side	Mud-Chara	July 7	C,E	300	28	18½	6.0-6.0
53-52	East Side	Mud-Chara	July 16	D	150	14	*36 3/4	6.0-6.0
61-52	East Side	Mud-Chara	July 30	B,E	300	11	14¼	6.0-6.0
68-52	East Side	Mud-Chara	Aug. 14	B,D,E	450	3	17½	6.0-6.0
Totals					4,350	122		

*Two nights, one day.
**1 mile below Polson.
***1½ miles below Polson.

GILL NET SETTINGS OUTSIDE POLSON AND YELLOW BAYS 1952

NET SET NUMBER	LOCATION	BOTTOM CHARACTER	DATE	NET LETTER	TOTAL FEET NET	NUMBER OF WHITEFISH	LENGTH OF SET (HOURS)	DEPTH RANGE (METERS)
25-52	Somers, Montana	Mud-sand	May 17	*****	450		—	1.5-4.5
39-52	Wild Horse Isle	Rock-Gravel	June 24	B,C,E	450	4	13½	3.0-22.5
40-52	Wild Horse Isle	Rock-Gravel	June 24	A,D	300	1	19 3/4	4.0-21.5
46-52	West Flathead Delta	Sand-Mud***	July 3	A,D	300	4	21	— —
47-52	South Flathead Delta	Mud ****	July 3	B,C,E	450	2	18	3.5-3.5
48-52	S.E. Flathead Delta	Mud	July 3	150x12 300x12	450	15	16 3/4	7.0-22.5
52-52	Big Arm Bay	Mud	July 14	150x12 300x12	450	2	17½	14.5-15.5
67-52	*Cliff Rocks	Rocky	Aug. 10	150x12 300x12	450	3	13½	20.0-56.5
79-52	**Bull Islands	Mud	Oct. 2	150x12 300x12	450	22	16½	12.5-18.5
TOTALS					3,750	53		

*Below Wood's Bay.
**Between Little Bull and Big Bull.
***_Potamogeton_ and _Elodea_ present.
****_Chara_ and _Elodea_ present.
*****Three 150x6 Nylon Gill Nets Montana State Fish and Game Dept.